PAEE/ALE 2023

INTERNATIONAL CONFERENCE ON **ACTIVE LEARNING** IN **ENGINEERING EDUCATION**

paee ALE Insper

Designing and Mastering Engineering Education for the Jobs of the Future

June 28th to 30th • São Paulo – Brazil

paee

PROJECT APPROACHES IN ENGINEERING EDUCATION

ALE

TITLE

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20th Active Learning in Engineering Education Workshop (ALE)
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PROJECT APPROACHES IN ENGINEERING EDUCATION

http://paee.dps.uminho.pt/

This is a digital edition.

WELCOME TO PAEE/ALE'2023

Dear Participants,

Welcome to the International Conference on Active Learning in Engineering Education (PAEE/ALE'2023). This marks the eighth collaboration between the International Symposium on Project Approaches in Engineering Education (PAEE) and the Active Learning in Engineering Education Workshop (ALE).

The theme of this year's conference is "Designing and Mastering Engineering Education for the Jobs of the Future." As engineering project challenges grow increasingly complex in the industry, engineers are required to possess skills and competences that allow them to efficiently resolve issues related to the design and operation of products and services within tight timelines. Consequently, the implementation of modern teaching and learning models becomes crucial for the training of future engineers. Educational institutions must therefore focus on preparing and equipping their teachers and mentors to become effective educators within this competitive professional environment. This year's event aims to enable the design of improved engineering programs and courses for students, while emphasizing the need for institutions to invest in modernizing teaching methodologies. It is important to recognize that the outcomes of educational efforts will only materialize in a few years when students fully realize their potential. Therefore, it is crucial to be prepared and invest in education now.

The conference program encompasses a diverse range of topics related to active and project-based approaches. These include reflections on the application of Problem-Based Learning (PBL), the design of curricula that incorporate PBL opportunities, tools for facilitating PBL classes, assessment of students' work, and lessons learned from adopting PBL methodologies.

Renowned keynote speakers from the field of Engineering Education will be present at this edition of PAEE/ALE to share their experiences with the participants. In addition, hands-on sessions will provide valuable opportunities for experiential learning, enabling participants to experiment and engage in discussions regarding the proposed concepts.

We hope that the International Conference on Active Learning in Engineering Education (PAEE/ALE'2023) serves as a productive forum where participants, with their ongoing commitment to continuing education, can discuss research and current practices within the challenging context of fostering globally aware engineers.

We would like to express our sincere gratitude to the participants who have made this event possible, as well as the support received from various individuals and organizations throughout the past year.

We hope you enjoy the conference that the PAEE/ALE team has meticulously prepared for you.

Luciano Soares & Fabio Miranda

(Chairs of the PAEE/ALE'2023)

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PAEE/ALE'2023 Invited Speakers

PAEE/ALE'2023 attracted renowned keynote speakers from different sectors to share their viewpoints on the direction of education, especially in engineering education in this new era. We are honoured to have the following inspiring keynote speakers:

Mark Somerville

Navigating Engineering Education for the Jobs of the Future: A Conversation

Mark Somerville is Provost and Professor of Electrical Engineering and Physics at Olin College of Engineering. He holds M.S. and Ph.D. degrees in electrical engineering from MIT, as well as an M.A. (first class honors) in physics from Oxford University. Dr. Somerville has collaborated extensively with other institutions, including the University of Illinois at Urbana-Champaign, TU-Delft, and others, to spread change in engineering education, particularly through the application of collaborative design techniques to curriculum revision processes.

Diana Mesquita

The Art of Doing Research in Engineering Education

Diana Mesquita is currently an invited Assistant Professor at the Universidade Católica Portuguesa, Faculty of Education and Psychology, Porto, Portugal. She holds a PhD in Educational Sciences, specialized in Curriculum Development from University of Minho. She delivered more than 80 workshops dedicated to teacher training in Portugal, Brazil, Colombia, Russia and Thailand. She participated in several national and international projects, organized more than 25 national and international conferences and has more than 80 publications of articles in international journals, book chapters and scientific events.

Irineu Gianesi

Curriculum Design for Competence Development

Gianesi is currently Dean of Academic Affairs at Insper, including responsibility for the design and implementation of new degree programs and curriculum innovation. He also led the team that designed and implemented one of the most innovative engineering programs in Brazil, launched at Insper in 2015. Prior to Insper, Dr. Gianesi was for 10 years a professor at the School of Engineering at the University of São Paulo, in Brazil. Dr. Gianesi has a Doctorate in Business Administration from the Cranfield University, U.K. He also has a master's and a bachelor's degree in engineering from the University of São Paulo. He is co-author of four books in the areas of operations management and curriculum and course design.

PAEE/ALE'2023 Programme

An overview of the program is shown below. Click on sessions to show more detail.

The conference will take place at Insper building #2 at: Rua Quata 200 - Vila Olímpia, São Paulo, SP

	28/06	29/06	30/06
08:00	Registration 4th floor		
08:30	Opening Ceremony + Registration Agile Labs, 4th floor	Registration 4th floor	Registration 4th floor
09:30	Keynote Mark Sommerville Agile Labs, 4th floor	Keynote Diana Mesquita Agile Labs, 4th floor	Keynote Irineu Gianesi Agile Labs, 4th floor
11:00	Break ☕ 4th floor	Break ☕ 4th floor	Break ☕ 4th floor
11:30	Design Challenge 211, 2nd floor	Workshops 1, 2, 3 Agile Labs / 311 / 312	Workshops 1, 2, 3 Agile Labs / 311 / 312
13:00	Lunch 🍽 5th floor Build. #1 Quata 300	Lunch 🍽 5th floor Build. #1 Quata 300	Lunch 🍽 5th floor Build. #1 Quata 300
14:30	Paper Sessions I, II, III Agile Labs / 311 / 312	Paper Sessions IV, V, VI Agile Labs / 311 / 312	Paper Sessions VIII, IX Agile Labs / 311
16:00	Break ☕ 4th floor	Break ☕ 4th floor	Closing Ceremony Agile Labs, 4th floor
16:30	Career Panel Agile Labs, 4th floor	Paper Session VII + Student session 311 / Agile Labs	
18:00	Welcome Party Vilinha Bar Rua Quata 293		
19:30		Conference Dinner Praça São Lourenço Rua Casa do Ator 608	

PAEE/ALE'2023 Detailed Programme

Details for each session are listed below.

Design Challenge

Workshops 29/06

1. **Haaukins: Cyber Security Training with Gamification***Pedersen, Jens Myrup**
2. **Workshop Introdution to Emotional Education in Engineering Education: a hands-on experience***Campos, Lílian B P**
3. **Creation and assessment of learning goals that support competence development***Orfali, Fabio*; Vieira, Fabio*

Workshops 30/06

1. **Reflecting on the delicate task of assessing learning in competency-based training in Engineering Education***Sauer, Laurete Zanol; Loder, Liane Ludwig; Villas-Boas, Valquiria**
2. **Hands-On Workshop on Building Assessments with Prairie Learn***Tavares , Tiago F*; Stabile Junior, Marcio Fernando*
3. **"Ethics pills": Including ethics in any engineering course, right now, right here***Romá, Miguel**

Student Session

1. **Sentiment analisys of comments made by students at the end of their internships using data mining.***Chan-Pavon, Miriam V.*; Menéndez-Dominguez, Victor H.; Gil-Herrera, Richard de J.; Escalante Eúan, Jesús F.*
2. **Perception of students and teachers about the skills trained in curriculum projects at an engineering school***Matumoto, Pedro Henrique S*; Mattasoglio Neto, Octavio; da Matta, Eduardo N; Nitz, Marcello*
3. **Introducing STEM projects in multidisciplinary teacher training***Batista, Filipe A*; Aragão, Isabelle R; Jesse A de Oliveira, Marcus MJAO; Maria Chagas E Cavalcante Koike, Carla; Viana, Dianne Magalhães; Yudi Mori Alves Da Silva, Jones*
4. **A PBL experience with second year students of Industrial Engineering** *Carvalho, Violeta*; Costa, Lino; Rodrigues, Cristina; Teixeira, Senhorinha*

Paper Session I - PBL

1. **Using a wireless power transfer project to enhance the understanding of the Electromagnetic Theory in a modeling and simulation framework.***El Hage, Fabio S*; Carareto, Rodrigo; Marmo, Carlos*
2. **The PBL methodology in engineering education: discipline description and analysis at the Institut National des Sciences Appliquées Lyon in France***Martins, Elayne; Junior, Alberto; Pedrosa, Paula Vieira; Amorim, Emanoel S.**
3. **Game development learning with PBL approach as a tool to assess computer engineering competences.***Freme, Pedro H E P*; Sanches, Tiago ; Soares, Luciano P*
4. **Applying Mirror Discipline Concept and Project Based Learning to enhance Active Learning** *MAESTRELLI, NELSON Carvalho*; Pekelman, Helio*
5. **A case study of gamification and PBL integration as an active learning pathway***MAESTRELLI, NELSON Carvalho**
6. **Engaging approaches to explore rigid body dynamics concepts in undergraduate engineering courses** *Paiva, Victor A S M*; Rodrigues, Caio Fernando; Moro, Franco; Barbieri, Frederico*

Paper Session II - Curriculum

1. **Institutionalization of University Extension through Integrative Projects: An Experience between a Food Industry and the Production Engineering from Mackenzie Presbyterian University***Saut, Ana Maria; Carvalhal, Marcelo A; Helleno, Andre L; VICENTE, SILMARA A S**
2. **University Extension as Complementary Training for Industrial Engineers***Vieira Junior, Milton V*; Guimarães, Gil; Severino, Maico*
3. **Safety Culture in Higher Education Institutions: Knowledge and Training preferences***Anacleto Filho, Paulo César*; Dall-Orsoletta, Alaize ; Carneiro, Paula M S; Colim, Ana; Leão, Celina P; Rodrigues, Matilde A.; Costa, Susana; Costa, Nélson*
4. **PBL in a University-Business cooperation in Engineering and Operations Management Master: challenges and opportunities***Alves, Anabela Carvalho*; Costa, Nélson; Lopes Nunes, Manuel; Sousa, Rui M.; Lima, Rui M; Carvalho, Dinis*

5. **Training for Digital Manufacturing: a multilevel teaching model***Rocha, Luis J*; Gaska, Adam; Savio, Enrico; Marxer, Michael; Battaglia, Christoph; Harmatys, Wiktor*

6. **Strengthening of Love and Meaning of Life in Engineering Students supported by Problem-Based Learning***Rojas, Sandra L*; Castelblanco, Carlos; Parra, Libia Yolanda; Acosta, Patricia; Muñoz, Giovanni*

Paper Session III - Active Learning

1. **Flipped Classroom teaching of mobile robotics***Martins, Thiago*; Forner-Cordero, Arturo; Archone, Maurício; Selestrim, Vinicius*

2. **Active learning in accessibility: Lessons and challenges from engineering classes in Northern Brazil***das Neves, Renato; Lima, Gabriel**

3. **Experiences in Team-based learning for Materials Engineering Program***Hirayama, Denise**

4. **Active Learning Approaches Applied in Teaching Agile Methodologies** *Tonin, Graziela Simone S*; Miranda, Fabio R; Kurauchi, Andrew T N; Montagner, Igor; Agena, Bárbara ; Jailson Barth, Fabrício*

5. **Active Methodology and Digital MKT: Experience report on the construction and application of the game in the classroom***Alves, Rebeka Coelho *; Araújo , Maria Valéria; da Silva, Dmitryev; Silva, mARINA; Galdino de Araújo, Afranio*

6. **Investigating Engineering Contributions in Hackathons: Metaverse and Blockchain as Key Components for E-commerce***Baptista, Rodrigo Martins*; Helleno, Andre L; Nicoletti, Alaércio; Gonçalves, Milca; Guimarães, Tatiane; Araujo, Rodrigo; Rocha, Rodrigo; V., Gabriel; Maksoud, Lucas; Matos, Davi; Rangel, Vinícius*

Paper Session IV - Soft Skills

1. **Emotional Education in Engineering Education: a hands-on experience***Campos, Lílian B P*; Figueiredo, Alice Cristina*

2. **Skills development with a focus on self-awareness and self-management: the power is in the student's hand***Campos, Lílian B P*; Pinto, Janaina A*

3. **Literacy(ies) and skills in times of digital education: exploring communication and interaction in digitally mediated learning worlds** *Correia, Joana D*; Henriques, Susana; Fernandes, Sandra R. G.; Abelha, Marta; Seabra, Filipa*

4. **Developing Teamwork with the aid of Reflection***Filho, Guy CDA*; Miranda, Fabio R; Tonin, Graziela Simone S; da Silva Marote Rodrigues, Gleice*

5. **Is it possible to form an engineer for the 21st century without considering the social sciences and humanities in their education?***Pasini, Regis*; Barreto, Gilmar*

Paper Session V - Tools

1. **ICT tools use in the scope of education in Engineering: a systematic review***Barbosa , Joana Pinto ; Costa, Nélson*; Costa, Susana; Leão, Celina P*

2. **Enhancing Learning Effectiveness with Online Educational Platforms: Insights from the Use of Prairie Learn in a Data Science Classroom***Tavares , Tiago F*; Stabile Junior, Marcio Fernando*

3. **Smart Digital Ecosystems for Cooperative Learning***Aragon, Rosane; Menezes, Crediné Silva de**

4. **Remote Laboratory Concepts and Practices during the COVID-19 Pandemic: An Experience Report***Szafir, Silvio*; Ferraz Júnior, Fábio; Licks, Vinicius; Rosa, Henrique; Campos, Hugo; Maiorquim, Antonio*

5. **Upgrading a TurtleBot3 robotics platform to support a Project-Based Computational Robotics course***Costa Lima, Lícia Sales*; Cuenca, Rogerio B; Montagner, Igor; Junior, Arnaldo; Miranda, Fabio R*

6. **Metaverse Workspaces for Active Learning – Brazilian Oil & Gas Company case***Azevedo Jr., Delmir Peixoto*; Muniz Jr., Jorge; Campos, Renato*

Paper Session VI - Assessment

1. **Digging into students' perception about peer and self-assessment***Romá, Miguel*; Ballester, David; López-Sánchez, Juan Manuel; Martínez-Marín, Tomás; Signes, José Antonio; Alavés, Vicent; Cazcarra, Víctor*

2. **Certificates and skill levels. Gamification applied to learning goals.***Sandoval, Leonidas*; Alves, Giovanna; Leite, João*

3. **The reformulation of methodological strategies in a Physics course - implementing assessment by competences in an Engineering program***Mattasoglio Neto, Octavio*; Cutri, Rodrigo; Stem, Nair*

4. **Evaluation of Students' Performance of a Project Based Learning Course on Elements of Computing Systems***Trevisoli, Renan*; Costa Lima, Lícia Sales; Corsi Ferrao, Rafael ; Fukunaga Gomes, Alex*
5. **Teamwork and peer assessment in the build of prototypes and ventures in the Introduction to Systems Engineering and Introduction to Industrial Engineering subjects supported by the project-based learning approach***Rojas, Sandra L*; Monroy, Sonia SM*
6. **People Competence Assessment based on Project Management Scenarios***de Souza, Mariane C*; Lima, Rui M; Mesquita, Diana*

Paper Session VII - Teaching Experiences and Reports I

1. **Innovations in Engineering Teaching Observatory: preliminary results about a Brazilian State***Campos, Lílian B P*; Izeki, Claudia A; Figueiredo, Vitor Guilherme Carneiro; Duarte, Jessyca Laryssa Galvão; Nagai, Walter A*
2. **Application of the initial phases of the SODA method as a tool for identifying root causes in the production area of a chemical industry***Marques, Beatriz D*; Silva, Caroline P; Gimiliani, Sofia S; Carvalhal, Marcelo A*
3. **A proposal for teaching-learning of Quality Management Subject using the TPACK (Technological Pedagogical Content Knowledge Framework) model.***Campos, Andromeda M.*; Leone, Robson; Prado, Ramon; Chagas, Helena; Brozeguini, Jardel; Ventorim, Diego; Gomes, Rodolfo*
4. **Applied teaching methodologies and practices in the development of the Final Course Paper (TCC) in engineering at FCA – Unicamp***Izuka, Jaime H*; Ignacio, Paulo S A; Suyama, Daniel Iwao; Paiva Okabe, Eduardo*
5. **Innovating the teaching of basic concepts of chemical kinetics through the use of analogies** *Ramirez Angulo, Javier**
6. **Proposal of Method for Risk Assessment of Failure in Undergraduate Final Project Report – UFPR (Undergraduate Thesis) when using Project-Based Learning** *Pereira, Jose Cristiano*; Sheremetieff, Alexandre; Alvarez, fabini*

Paper Session VIII - Teaching Experiences and Reports II

1. **Winning the European Cyber Security Challenge 2022: What did We Learn?***Pedersen, Jens Myrup*; Hansen, Adam Blatchley; Torres, Mateus Halbe*
2. **Lesson learned from an international cross-disciplinary engineering collaboration: a case study of the "Educado" project***Britze, Daniel*; Torres, Mateus H.; Rodrigues, Giovanna L. ; Gomes, Paulo C. R.; Monteiro, Simone Borges Simão Monteiro Borges; Pedersen, Jens Myrup; Russo, Daniel*
3. **Insights into Scholarly Teaching and Research in Brazilian Engineering Education: An Analysis of Last Year's Cobenge Active Learning Papers***Viana, Dianne Magalhães*; Villas-Boas, Valquiria*
4. **Active Learning Methodology in Mechatronic Project Education: A Case Study***Ferraz Júnior, Fábio*; Szafir, Silvio; Magno de Oliveira Valente, Carlos; Licks, Vinicius; Bottene, Alex C; Pollettini Marcos, Gustavo; Ferreira Alves, Israel; Bufacchi, Paulo*
5. **Is better academic performance in engineering synonymous with more entrepreneurial capacity? A cross-sectional study of the correlation between academic grades and business creation by graduates of Production Engineering at Universidade Federal do Rio de Janeiro***Arruda, Humberto H*; Silva, Édison Renato; Uziel, Daniela*

Paper Session IX - PBL II

1. **Project-Based Learning in Industrial Engineering and Management: analysis of three curricular projects at University of Minho***Sousa, Rui M.*; Alves, Anabela Carvalho; Lima, Rui M; Fernandes, Sandra; Mesquita, Diana; Carvalho, Dinis*
2. **Experiencing the implementation of Project-based Learning (PBL) curriculum in a Graphic Design Bachelor: goals, challenges and outcomes.***Uébe-Mansur, Andre Fernando*; Oliveira, Joelma; Neves, Alan; Facco, Jaqueline; Torres, Roberta*
3. **Biomechanical Project Design: Development of a Pump for Mechanical Circulatory Assistance***Turri, Fabio*; Barbieri, Frederico ; Valente, Carlos*
4. **Experience in Project-Based Learning (PBL) applied to remote and face-to-face classes in the Materials Engineering Program at a Brazilian university.***Bento dos Santos, Esoly Madeleiene**
5. **Cross-semester student-centered integration project in mechanical engineering***Marzolla, Rafael Amoroso*; Bufacchi, Paulo; Bottene, Alex C; Ferreira Alves, Israel; Pollettini Marcos, Gustavo; Galdino dos Santos, Raphael*
6. **A case study on Project Based Learnig applayed to industrial automation and production systems***Valente, Carlos; Pinto, Lie Pablo Grala*; Ferraz Júnior, Fábio; Szafir, Silvio; dos Santos, Francisco; Andrade, Renato; Nascimento, Allan*

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Innovating the Teaching of Basic Concepts of Chemical Kinetics Through Analogies

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Abstract

An educational qualitative research project using analogies related to economic aspects of any person receiving a periodic salary and making payments for various reasons, such as acquiring goods, was conducted so students could conceptualize the parameters that determine a kinetic study, such as the initial concentration and the half-life, and understand that its management is experimental. The analogies were applied in samples of students from different disciplinary areas of engineering, and through problem-solving, the efficiency of the analogies used was evaluated with good results, given that they were based on constructivism.

Keywords: Speed, order and reaction constant, half-life, educational innovation, higher education

1 Introduction

Chemical kinetics is a topic studied in one or more subjects of chemical engineering, biotechnology, or the chemical area in general, or in subjects whose names have a direct connection or appear similar, have the same title, or in other subjects that have it as a specific topic, such as physical chemistry, biochemistry, or general chemistry, [Valenzuela, 2002].

One way to achieve an understanding of some of the main concepts of chemical kinetics philosophy and introduce the study of this topic is by supporting it with analogies to events of everyday life that students know well and can connect personally [Bender, 2007].

Analogies are comparisons between domains of knowledge that maintain a relationship of similarity and contribute to the construction and development of scientific knowledge and its subsequent communication, so they are considered fundamental in the teaching-learning process of sciences.

If teachers manage to get the student to grasp basic concepts of chemical kinetics, for example, the meaning of initial concentration or half-life, and that it is fundamentally an experimental science, they have a good starting point to teach more advanced concepts of this subject, with the benefits that this can bring.

2 Background

Using analogies to teach science is a strategy that teachers of chemistry and other sciences have used, sometimes more or less empirically, to facilitate understanding a given topic.

Several works describe how using analogies in teaching chemistry and other sciences has helped the authors in their teaching work in various academic tasks, as mentioned by Oliva [2005]. He assures that analogies constitute a resource for teaching science; they link to the conceptual field by changing existing intuitive ideas. They aid the development and learning of scientific procedures in recognizing and differentiating concepts, establishing causal relationships, making predictions, and formulating and evaluating hypotheses, models, and theories. According to this author, analogies can be handy instruments for developing imagination, creativity, attitudes, and skills required to handle scientific models and reality.

Linares [2005], a chemistry professor at a Colombian university, researched using analogies in the Department of Chemistry courses as part of her doctorate in the didactics of experimental sciences, completed at the Autonomous University of Barcelona. She learned that many of the examples and comparisons with everyday situations that she frequently used throughout 25 years of teaching were called analogies and that they had been widely studied, and that there were various theories to explain these reasoning and various models and proposals to use these strategies correctly.

Linares explains that an analogy is a comparison of domains of knowledge that have a particular relationship of similarity, offering a helpful way to acquire knowledge that has already been established, i.e., its purpose is to present explicit comparisons between the relevant structures of the known domain and the unknown, while examples used in learning processes seek to make familiar what until then is unknown. She describes that an analogy must be pragmatic for its purpose to be clear, with semantics using terms with similar meanings in both domains and structural similarity between the objects.

Bender and his collaborators [2007] analyzed several chemistry books widely used in chemistry teaching at high school and higher levels to detect which analogy models were used to explain the topic of chemical kinetics.

Although several texts did not present any analogy to deal with this topic, the ones most recommended by teachers did, for example, Whitten's, Brown's, or Brady's *Chemistry*. Whitten used the preparation of a sandwich and its ingredients as an analogy for calculating the rate of a chemical reaction and the reactants' consumption or the formation of the products. Another analogy concerning a body's velocity was the speed of an automobile to explain the notion of reaction rate as a change of concentration through time. This appears in several works; for example, in Brady's book, on page 492, the following appears: "The rate of any chemical reaction can be expressed as the ratio of the change in the concentration of a reactant (or product) to a change with time. This is exactly analogous to the speed of a car, expressed as the change of position (the distance traveled) divided by the travel time. In this case, the speed could be expressed in kilometers per hour. With chemical reactions, the rate is usually expressed in moles per liter per second."

The same analogy on page 492 of Brown's book (1998) explains this concept: "The speed of an event is defined as the change that occurs in a time interval. Whenever we speak of speed, we must introduce the notion of time. For example, the speed of a car is expressed as the change in position of the car over a specific period. The units of this speed are usually kilometers per hour (km / h), that is, the amount that changes (position, measured in kilometers), divided by the time interval (hours). Similarly, we can talk about the speed of a chemical reaction."

Without analyzing the analogies used in detail, it is found that not all can work and that epistemological vigilance in teaching is required. Analogies can be classified into two groups, those based on figurative models with a symbolic value and those based on explanatory models, the most common in this topic were the former. An example is a high jump athlete to explain the concept of activation energy and the initiation of a reaction from molecular shocks. Another is a bear that wants to reach a river to eat fish; it needs to go over a hill with a tunnel through it: The bear passing through the tunnel would reach the river more quickly. This can be an analogy to explain the concept of a catalyst whose role is to modify the activation energy of a given chemical reaction. Regarding biological catalysts such as enzymes, one of the most used analogies in its study was that of a key uniquely cut to fit a lock to compare with the specificity of a unique and specific substrate.

He concludes that analogies can be very useful in teaching chemistry topics, but this depends on how they are used in the classroom.

3 Methodology

The analogies used in this case were applied throughout several semester courses and were based on the monthly salaries of three workers who can be called by any name, such as Alex, Beto, and Cesar. It was explained that the money that any of them has at any time was represented by [$]; for example, Beto's would be $[\$]_B$, and if Cesar at any given time had 5000 pesos, it would be expressed as $[\$]_C = 5000$. Also, it was clarified that a sub-index within the bracket indicated the days that had elapsed since they received their salary; for example, $[\$_1]_A = 9500$ means that one day after Alex receives his salary, he has 9500 pesos.

After these explanations, students were presented with the following scheme:

Table 1. Example of the analogies used with wages in pesos.

Time "t" in days	Alex $[\$]_A$	Beto $[\$]_B$	Cesar $[\$]_C$
0	15000	30000	60000
1	14500	27147	50000
2	14000	24560	40000
3	13500	22223	30000
4	13000	20108	25000
5	12500	18195	20000
6	12000	16463	15000
7	11500	15000	20000
8	11000	13479	15000
9	10500	12196	12500
10	10000	11035	10000
11	9500	9985	7500
12	9000	8175	6250
13	8500	7397	5000
14	8000	7500	3750
15	7500	6056	3125
16	7000	5480	2604
17	6500	4958	2083

The students were asked how much money Alex had on the third day, Beto on the fourth, Cesar on the second, etc., to check that they understood the nomenclature. Then the students were asked if they worked in a bank as credit investigators, who of the three would be granted a credit card more easily. Most answered Cesar because he had the highest salary, which was observed on the line with the time equal to zero days, i.e., when not a single day had passed. When asked to analyze what happened with each character, all the students agreed that each person's money decreased as the days passed because they had to make payments for services and acquire products. They indicated there was a relationship between the elapsed days represented by "t" and the balance of money [$].

Then they were asked to analyze the money on the fifteenth day for Alex, the seventh for Beto, and the third for Cesar, and what they noticed. Although it took them a while to do it, in the end, everyone agreed that in the indicated rows, exactly half of the initial money or salary remained and that the elapsed time for that to happen was different for each of the three persons. At that time, the teacher clarified that this period was called the half-life and that it was indeed when the starting salary decreased to half. It was represented with the special notation "$t_{1/2.}$" The teacher pointed out that Alex was more solvent due to having a longer half-life than the other two characters, although he earned less, and, t by the way, banking institutions usually only consider the salary or initial money [$\$_o$], is not a guarantee of the economic solvency of the credit card applicant and, in any case, the two parameters should be taken into account. Once the students understood this, they were asked to graph [$] vs. t for the three people and to point out the initial money and half-life, which they did without a problem.

From there, it was not complicated to make them understand a series of situations in this regard, such as t = $t_{1/2}$ when [$] = [$\$_0$]/2, or that because each character was different, only through research that included both [$] and t, could one know a specific person's economic situation at a given moment. It was also not difficult to make the students see that one could obtain an initial average velocity of the money variation over time or obtain an equation that would relate the [$] to t. It was even possible to speak of an "order" of spending and a specific constant of spending money without it seeming strange to the students.

When the students showed that they had understood the explanations, which certainly captured their attention favorably, the topic of chemical kinetics began, using a reaction of a single reactant "A" that gave products "P" and the analogies of the [$] with the molar concentration [A] and that the initial molar concentration [Ao] decreased as time "t" passed. The analogy that the half-life of a reaction was that time when the initial concentration decreased by half and so on, concepts related to chemical kinetics such as the specific reaction rate constant, reaction order, methods for determining them from experimental data, the deduction of mathematical equations of the order zero-one-two, and the application of the Arrhenius equation, in general - concepts that are used in chemical kinetics, as presented in a chemistry book like Chang's. (Chang, 2002).

4 Results

The students (about 90 %), were very motivated when describing the three characters' cases and the variations in their economic situations. They had no problem understanding them, and it served very well as an analogy to deal with the subject of chemical kinetics in such a way that if someone had difficulties in understanding some concept, for example, in the resolution of a given problem, It could be transferred to the corresponding analogy and the student grasped it again. However, some students (about 25 %), understood the example of the characters very well, but when they entered the subject of chemical kinetics, they resisted studying it, perhaps because they systematically rejected the different topics of chemistry. A 10 % of students commented that they did not like the analogies because they were confused by where an analogy ended and the subject began, so they preferred orthodox teaching.

5 Conclusions

Most students (about 80 %), understood the concepts of initial concentration, half-life, reaction order, and the specific reaction rate constant. Even students studying other disciplines, such as industrial or mechanical engineering, found analogies very enjoyable and a straightforward way to approach this topic; they could solve zero-first-second-order problems objectively. However, a minority of students (less than 15 %), were against its use, arguing that they were confused, distracted, and preferred to approach the subject directly without any analogies.

In conclusion, we carried out an innovative proposal using analogy as a didactic strategy for students to achieve significant learning, relating daily life activities to scientific aspects.

"Analogies offer a different way of thinking to reinforce science teaching, teacher training, and professional performance"(Aubusson et al., 2005, p.8).

6 References

Aubusson, P. J., Harrison, A. G. and Ritchie, S. M. (2005). Metaphor and analogy in science education. Dordrecht: Springer.

Brady, J.E., (1999) Química Básica, 2ª Edición. Ed. Limusa Wiley.

Bender, G. Cutrera, G., Deafo, A., (2007). Cinética química y analogías; un análisis de las propuestas de enseñanza. Jornada de Enseñanza e Investigación Educativa en el campo de las Ciencias Exactas y Naturales. Argentina

Brown, T., LeMay, E., Bursten, B., Escalona y García, H. J., Escalona, M. C. R., & Doria Serrano, M. d. C. (1998). *Química: La ciencia central* (7a. ed.--.). México D.F.: Prentice Hall.

Chang, R; College, W. (2002). Química. 7ª Edición. McGraw Hill Interamericana Editores S. A. de C.V. México

González, B., Moreno, T., Fernández., (2000). Modelos de enseñanza con analogías. XIX Encuentros de Didáctica de las Ciencias Experimentales. Madrid. Actas de los XIX Encuentros de Didáctica de las Ciencias Experimentales 161-169

Linares, R., El uso de analogías en los cursos del Departamento de Química de la Universidad del Valle. Instituto de Educación y Pedagogía. Universidad del Valle. Santiago de Cali. Colombia (2005).

Oliva, J.M. (2006). Actividades para la enseñanza /aprendizaje de la química a través de analogías Revista Eureka sobre Enseñanza de las Ciencias. 3(1), pp. 104-114. España.

Medina, J.V., Martínez, R.A., Ramírez. O.J. (2002 Otra analogía para definir el equilibrio química. Revista psicológicas y sociológicas. La Habana. CUBA.

Rodríguez, M. García (2011). Aprendiendo a través de analogías. CIPS. Centro de investigaciones psicológicas y sociológicas. La Habana.

Valenzuela-Zapata M.A., Ancheyta-Juárez, J., (2002). Cinética Química para Sistemas Homogéneos Ed. Instituto Politécnico Nacional. México.

Whitten, K. W., Davis, R. E., Peck, M. L., & Stanley, G. G. (2015). *Química* (10a. ed. --.). México D.F Cengage Learning.

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Training for Digital Manufacturing: a multilevel teaching model

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Abstract

The changes observed from last years in the field of manufacturing and production engineering popularly known as "Fourth Industrial Revolution", utilizes the achievements in the different areas of computer sciences, introducing new solutions at almost every stage of the production process, just to mention concepts such as: mass customization, cloud computing, knowledge-based engineering, virtual reality, rapid prototyping, or virtual models of measuring systems. To effectively speed up the production process, and make it more flexible, it is necessary to tighten the bonds connecting individual stages of the production process and to raise the awareness, and knowledge of employees of individual sectors about the nature and specificity of work in other stages. It is important to discover and develop a suitable education method adapted to the specificities of each stage of the production process, becoming an extremely crucial issue to properly exploit the potential of the fourth industrial revolution. Because of it, the project "Training for dimensional metrology in digital manufacturing" (T4D) intend to develop training material for digital manufacturing including content for design, manufacturing, and quality control with focus on coordinate metrology and portable measuring systems. In this paper, the authors present an approach for using an active learning methodology for digital manufacturing. T4D main objectives is to develop a multilevel learning experience (apprenticeship up to master's degree studies) and the related educational approach that can be adapted to different levels. The process to create the underneath methodology is also described. The paper will share the steps to achieve the aims of the project (training model for digital manufacturing): 1) surveying the stakeholders, 2) defining the learning aims; 3) producing all contents and curriculum 4) training for tutors and 5) pilot courses test and improvements.

Keywords: Blended Learning; Industry 4.0; Active Learning; Digital Manufacturing

1 Introduction

We are facing changes that are observed from few years in the field of manufacturing and production engineering popularly known as "Fourth Industrial Revolution" (Schwab, 2017) and implications on training and teaching utilizes the achievements in the different areas of computer sciences, introducing new solutions at almost every stage of the production process, just to mention concepts such as: mass customization, cloud computing, knowledge based engineering, virtual reality, rapid prototyping or virtual models of measuring systems. To effectively speed up the production process and make it more flexible, it is necessary to tighten the bonds connecting individual stages of the production process and to raise the awareness and knowledge of employees of individual sectors about the nature and specificity of work in other stages. As an example of such diversity the training of industrial design students in field of coordinate metrology can be indicated, which allows them to design the product more consciously taking into consideration also the requirements of quality control departments (Rocha, Savio, Marxer, & Ferreira, 2018).

Unfortunately, basing on many feedbacks given by industrial partners of project's consortium members the understanding of mentioned relations is very limited in practice. This is why we concluded that finding and developing appropriate education methods adapted to the specifics of individual stages of the production process becomes extremely important issue which can be crucial to properly exploit the potential of the fourth industrial revolution. Because of it, we developed enriched training material for digital manufacturing including content for design, manufacturing and quality control with main focus on coordinate metrology and portable measuring systems as all participating organisations have coordinate metrology background (Stojadinovic, 2021; Savio, De Chiffre, Carmignato & Meinertz, 2016; Savio, 2012; Marxer, Rocha, Araújo & Kuster, 2015). In this project we take care of the skills gaps and mismatches that occurs since digital manufacturing is a new field not common to students, teachers and a wide range of workers in industry. During the project, innovative learning material covering the new aspects in a digital era was developed. By this, we develop learning material for the field of digital design (Qin & Cheng, 2017), digital manufacturing (da Silva, Shinohara, de Lima, Angelis & Machado, 2019), and quality assurance (Powell, Eleftheriadis & Myklebust, 2021; Ghiotti et al., 2015)). The development was based on modern learning approaches e.g. blended learning including different learning forms like e-learning, face-to-face lessons, workshops, etc. Special attention was given to remote learning possibilities (Ober, 2022), which is of crucial importance recently because of the recent situation in which we were put by COVID-19 pandemic that exposed many imperfections in this field (Bailey, Duncan, Murnane, & Au Yeung, 2021). The learning forms was chosen in a learner centred way to ensure high efficiency, and effective as well as motivating learning. In T4D we covered a wide range of target group in education institutions as well as in industry. The target group in education institutions was from secondary school up to higher education in universities. The target group in industry covered the range from beginners to experienced workers in the fields of design, manufacturing and quality assurance.

To ensure the success of the project and the sustainability of the outcomes, the educators, and educational leaders as well as the support staff have to be trained how to deal with the new aspects in the whole chain of digital manufacturing starting from design up to quality assurance. New concepts for the educational leaders were adopted that allow to include the aspects in the regular teaching activities and ensure an increase of the attractiveness of technical jobs (Katzis, 2018). The teachers and support staff interacting with students and/or industry participants will be guided e.g. in train the trainer activities (Lane & Mitchell, 2013) or with guidelines how to use the new learning concept and learning material.

2 Needs evaluation

The project aimed at finding and developing appropriate education methods adapted to the specifics of individual stages of the production process (design, manufacturing, quality control), which is extremely important issue that may be crucial to properly exploit the potential of the fourth industrial revolution. For that, it is needed to develop attractive training material for digital manufacturing including content for design, manufacturing and quality control, showing dependencies and relations between these production stages.

In order to evaluate the needs and contexts, the partnership defined a survey with several questions that was supposed to be more conclusive and representative. The partners sent the request to students, teachers, and other stakeholders like content developers, involved in the educational process and invited them to answer. The survey was run in all partner countries (Portugal, Italy, Germany, Switzerland, and Poland) and was conducted in their native five languages and in English. It was possible to collect 249 surveys. The most important information taken was that the answers came from educators/teachers that are working mainly at University level, with minor contribution from high schools level (professional courses).

These results of the survey were very indicative how the learning approach/methods, and learning aims, must be crossed with the aim of the project as well with the public target needs and expectations. The project was focused in a BLearning (i.e. blended learning) pedagogical approach (Peres & Lima, 2014), where the workshop and project work methods are very appreciated by students. These workshops schemas should take in account the available spaces and equipment inside of teaching entities showed in the answers.

When asked about "which technologies/tools they consider most important in the near future", CAD/CAE software is the most considered by respondents, followed by additive manufacturing and Cyber-physical systems (figure 1).

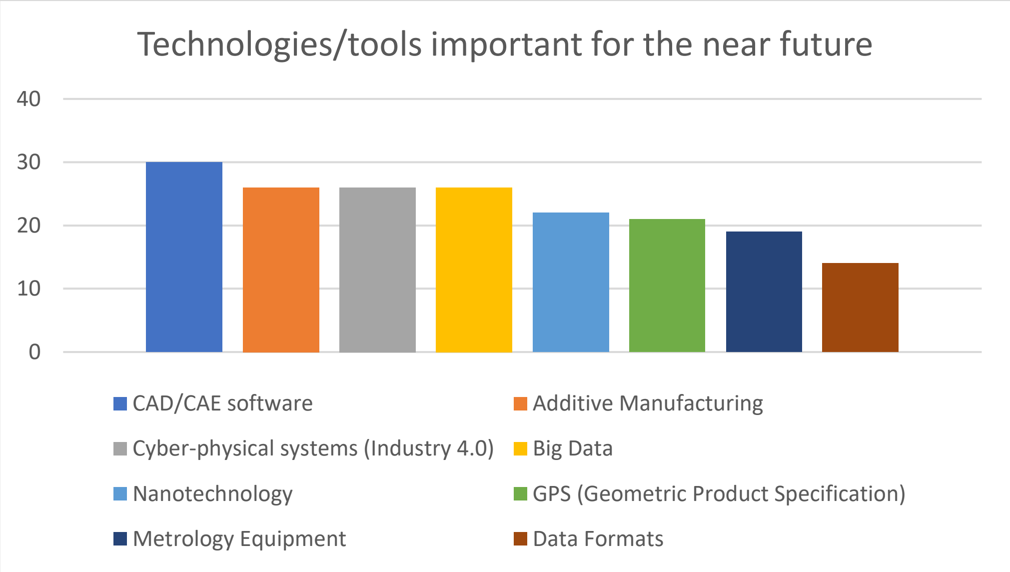

Figure 1. Answers for "which technologies/tools they consider most important in the near future?".

Another important result was mentioned that the role of the teacher/tutor still is very important for the students, for the lecture, and mainly for the practical sessions. The users also showed their preferences for interactive learning approach and must be adapted to different digital platforms (desktop, tablet, mobile, etc.), and virtual/augmented reality besides if be present in a small presence it indicates that it could be a new trend.

3 Defining the learning aims

The structure of the learning aims, which will spread in several learning modules, is based on a three-level approach, in order to take into account the prior knowledge of each individual learner (apprenticeship, bachelor, and master levels) and for meeting the needs of potential users. The learning content is distributed in referred levels: design, manufacturing, and verification workflow, as shown in Figure 2.

DESIGN	1. Definition of the product concept and functions 2. Definition of the product specifications 3. Preparation of the digital model of the product
MANUFACTURING	4. Identification of manufacturing requirements 5. Manufacturing equipment selection 6. Materials and manufacturing process preparation 7. Manufacturing process execution 8. Manufacturing post processing 9. Management of manufacturing environment
VERIFICATION	10. Identification of measurement requirements 11. Measurement equipment selection 12. Workpiece and measuring system preparation 13. Measurement process execution 14. Result evaluation process 15. Management of measurement environment

Figure 2. Three levels distribution of the learning aims.

4 Learning contents production

Due the actual demanding of learners, it´s supposed to have available contents with a high level of interactivity and good graphics (Alsadhan, Alhomod, & Shafi, 2014). Additionally, thinking in future use in learning management systems, the training modules were created in accordance with the same design rules, and are made up of an open-source software tool "ExeLearning" (Silalahi, 2020) which specifies a technical model that is subsequently used by development partners. A didactical template for further production has been defined for each of the learning modules, with a logical path for the learner and for the tutor, as shown in Figure 3.

Figure 3. Screenshot from a learning module created with eXeLearning tool.

During the creation of the learning modules contents, the authors included in each LM different approaches for increasing the active learning (Hartikainen, Rintala, Pylväs, & Nokelainen, 2019) such as: Exercises in different ways to traditional questions like true and false, but also include some animated games (Markopoulos, Fragkou, Kasidiaris, & Davim, 2015). Additionally, the consortium made employed techniques to participate in their learning by pondering, talking about, looking into, and developing answers. During the workshop phase, students put their newly acquired abilities into practice, work through measuring challenges, face difficult decisions, suggest solutions, and articulate concepts in their own terms.

As planned, the consortium promoted training activities for the trainers, passing teaching innovative methods developed in this T4D project for future tutors. The needs and requirements of the individual methods such as eLearning, presence-based lessons as well as hands-on workshops were taken into account to train the trainers. During this phase, it was practised in a simulation environment using invited students and teachers to test all approaches. During the discussions between partners, it was identified the need of including some communications skills for the tutors. It sounds basic for the activity, but communication skills are essential, because effective communication is critical for building strong relationships with students, creating a positive learning environment, and promoting student success (Xie & Derakhshan, 2021). For filling this gap for traditional technical teachers, we invited a teacher expert in communication skills for several professionals including lawyers, engineers and actors.

During the writing process of this paper, the consortium is organising pilot courses, where students from apprenticeship, bachelor, and master levels are involved in a way to get feedback about the quality of the contents, delivery of training, and connection with the tutors. As soon we get this feedback, the consortium will make any improvement needed, and implement any interesting given suggestion.

5 Conclusion

The innovation of this project is bringing together the training needs of different target groups that must collaborate in industry for product development covering new approaches in design, manufacturing, and quality assurance.

This project targets students from apprenticeship up to master level that must be trained in new approaches of modern product development and manufacturing of products and assemblies to make them fit to enter the industrial career and with that strengthen the power of European industry in a sustainable way (Xu, Lu, Vogel-Heuser & Wang, 2021).

The digitisation of product development requires a broad view of the several aspects of the steps of product development. New development in the digital era demands new training concepts as well as new training content (Amhag, Hellström & Stigmar, 2019). New developments use product and manufacturing information, also abbreviated as PMI that conveys non-geometric attributes in 3D computer-aided design (CAD) and Collaborative Product Development systems necessary for manufacturing product components and assemblies as well as their quality assurance.

New approaches such as Model Based Definition (Goher & Al-Ashaab, 2021) or working with Digital Twins (Perno & Haug, 2022) in different steps of product development and manufacturing need innovative and seamless training that is developed and covered in this project. With that innovative approach and the knowledge delivered, communication between these groups can be adjusted in a way that the requirements of the partners involved in the development and manufacturing.

Project partners will also continue to offer blended learning courses for third parties (technical schools, universities, and industry) after the project end, using the newly developed materials and tools. Course fees will be applied to cover the organizers' costs as a sustainable strategy.

The CMTrain e.V. Association (http://www.cm-train.org) which is one of this project participants, that was founded 18 years ago at the end of a European-funded project "EUKOM" (Weckenmann & Beetz, 2006), will continue to provide global access to high-quality learning content and teaching practices in English, French, German, Italian, Polish, Portuguese, Romanian, as well as the transfer of best practices in VET of employees in the manufacturing industry. The sustainability of the Association is guaranteed by annual membership fees and fees for the preparation of individual certificates for successful learners. The CMTrain Association will also coordinate efforts for maintaining the learning materials on the highest quality level by periodic revision of the learning content. The innovative training concept will significantly increase equality of opportunity when it comes to accessing learning content. Companies and learners in, for example, emerging markets that do not have widespread modern infrastructure will be able to benefit from this training concept.

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7 References

Alsadhan, A. O., Alhomod, S., & Shafi, M. M. (2014). Multimedia based E-learning: Design and integration of multimedia content in E-learning. International Journal of Emerging Technologies in Learning (Online), 9(3), 26. Chou, C. (2003). Interactivity and interactive functions in web-based learning systems: a technical framework for designers. British journal of educational technology, 34(3), 265-279.

Amhag, L., Hellström, L., & Stigmar, M. (2019). Teacher educators'' use of digital tools and needs for digital competence in higher education. Journal of Digital Learning in Teacher Education, 35(4), 203-220.

Bailey, D. H., Duncan, G. J., Murnane, R. J., & Au Yeung, N. (2021). Achievement gaps in the wake of COVID-19. Educational Researcher, 50(5), 266-275.

CMTrain. (n.d.). http://www.cm-train.org/.

da Silva, E. H. D. R., Shinohara, A. C., de Lima, E. P., Angelis, J., & Machado, C. G. (2019). Reviewing Digital Manufacturing concept in the Industry 4.0 paradigm. Procedia CIRP, 81, 240-245.

Ghiotti A, Schöch A, Salvadori A, Carmignato S, Savio E (2015). Enhancing the accuracy of high-speed laser triangulation measurement of freeform parts at elevated temperature. CIRP ANNALS, vol. 64/1, p. 499-502, ISSN: 0007-8506, doi: 10.1016/j.cirp.2015.04.012

Goher, K., Shehab, E., & Al-Ashaab, A. (2021). Model-Based Definition and Enterprise: State-of-the-art and future trends. Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 235(14), 2288-2299.

Hartikainen, S., Rintala, H., Pylväs, L., & Nokelainen, P. (2019). The concept of active learning and the measurement of learning outcomes: A review of research in engineering higher education. Education Sciences, 9(4), 276.Felder, R. M., & Brent, R. (2009). Active learning: An introduction. ASQ higher education brief, 2(4), 1-5.

Katzis, K., Dimopoulos, C., Meletiou-Mavrotheris, M., & Lasica, I. E. (2018). Engineering attractiveness in the european 17 uropean educational environment: Can distance education approaches make a difference?. Education Sciences, 8(1), 16.

Lane, A. J., & Mitchell, C. G. (2013). Using a train-the-trainer model to prepare educators for simulation instruction. The journal of continuing education in nursing, 44(7), 313-317.Kelly, D. (2008). Training the trainers: towards a description of translator trainer competence and training needs analysis. TTR, 21(1), 99-125.

Markopoulos, A. P., Fragkou, A., Kasidiaris, P. D., & Davim, J. P. (2015). Gamification in engineering education and professional training. International Journal of Mechanical Engineering Education, 43(2), 118-131.

Marxer, M., Rocha, L., Araújo, N., & Kuster, R. (2015, June). CMtrain-Remote training in Coordinate Metrology. In International Conference on e-Learning (p. 201). Academic Conferences International Limited.

Ober, J., & Kochmańska, A. (2022). Remote Learning in Higher Education: Evidence from Poland. International Journal of Environmental Research and Public Health, 19(21), 14479.

Peres, P., Lima, L., & Lima, V. (2014). B-learning quality: dimensions, criteria and pedagogical approach. European Journal of Open, Distance and E-Learning, 17(1), 56-75.

Perno, M., Hvam, L., & Haug, A. (2022). Implementation of digital twins in the process industry: A systematic literature review of enablers and barriers. Computers in Industry, 134, 103558.

Powell, D., Eleftheriadis, R., & Myklebust, O. (2021). Digitally enhanced quality management for zero defect manufacturing. Procedia CIRP, 104, 1351-1354.

Qin, S. F., & Cheng, K. (2017). Future digital design and manufacturing: embracing industry 4.0 and beyond. Chinese Journal of Mechanical Engineering, 30(5), 1047-1049.

Rocha, L., Savio, E., Marxer, M., & Ferreira, F. (2018, June). Education and training in coordinate metrology for industry towards digital manufacturing. In Journal of Physics: Conference Series (Vol. 1044, No. 1, p. 012026). IOP Publishing.

Savio, E., De Chiffre, L., Carmignato, S., & Meinertz, J. (2016). Economic benefits of metrology in manufacturing. CIRP Annals, 65(1), 495-498.

Savio, E. (2012). A methodology for the quantification of value-adding by manufacturing metrology. CIRP ANNALS, vol. 61/1, p. 503-506, ISSN: 0007-8506, doi: 10.1016/j.cirp.2012.03.019

Schwab, K., 2017. The fourth industrial revolution. Currency.

Silalahi, M. V. (2020). Development of E-Modules Based on Exe-Learning on Topics of Reaction Rate Against Student Learning Outcomes Mechanical Engineering. IJECA (International Journal of Education and Curriculum Application), 3(2), 114-120.

Stojadinovic, S. M., Majstorovic, V. D., Gąska, A., Sładek, J., & Durakbasa, N. M. (2021). Development of a coordinate measuring machine—based inspection Planning system for industry 4.0. Applied Sciences, 11(18), 8411.

Weckenmann, A., & Beetz, S. (2006, September). TRAINING IN COORDINATE METROLOGY EUKOM: MADE IN EUROPE–OPEN TO THE WORLD. In Proceedings of XVIII IMEKO World Congress Metrology for a Sustainable Development, Rio de Janeiro, Brazil (pp. 17-22).

Xie, F., & Derakhshan, A. (2021). A conceptual review of positive teacher interpersonal communication behaviors in the instructional context. Frontiers in Psychology, 12, 708490.

Xu, X., Lu, Y., Vogel-Heuser, B., & Wang, L. (2021). Industry 4.0 and Industry 5.0—Inception, conception and perception. Journal of Manufacturing Systems, 61, 530-535.

University Extension as a Complementary Formation of Industrial Engineers

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Abstract

Recently, all Engineering courses in Brazil had to follow the new National Guideline for Engineering Courses (according to the Resolution #2/2019, of the Federal Council of Education). New curricula, based on competences, were supposed to be deployed until 2022, and these new curricula should privilege University Extension. Almost at the same time, the Resolution #7/2018, also of the Federal Council of Education, established the Guidelines for the Extension on the Brazilian Higher Education, defining the understanding of University Extension, the ways in which it can be done, and establishing that the amount of 10% of the total duration of the courses should be fulfilled with extension activities. With these new regulations, the management teams of undergraduate courses were faced with updating the curricula, without having references. This paper reports the process of construction of a Curricular Referential for Extension Activities for Industrial Engineering Courses in Brazil. Based on the legal rules and on the participation of the community, ABEPRO approved a referential document to be used as a guide for the courses on the process of new curricula proposal.

Keywords: University Extension; Engineering Formation; Guidelines for Engineering Courses.

1 Brief History of Recent Engineering Formation in Brazil

Since 1996, after the passing of the Federal Law 9394/96, also known as Law of Education Guidelines and Bases, engineering courses curricula could change and they were no longer obliged to follow a "minimum curriculum", as it was established before. The Law defined that "Curricular Guidelines" should be defined for each group of courses, and that these guidelines should point the curricular components and contents that should compose the curricula of the courses [1].

In the case of Engineering Courses, the Resolution 11/2022 of the Federal Education Council (CFE) established the topics and contents that should be considered for the formation of an engineering course curriculum. The Resolution defined that an amount of about 30% of the total load of the course should be dedicated to Basic Contents of the engineering formation (Mathematics, Physics, Chemistry, Informatics, Design, among others); another amount of 15% should be dedicated to a Basic Professional Content (focused in the area of the course, ex.: Product Management, Production Management, Industrial Facilities and others, in the case of Industrial Engineering courses); and the remainder load should be dedicated to deepening the topics of the professional formation [2].

In 2019, the CFE approved the new Guidelines for Engineering Courses [3], establishing that the engineering formation should be focused on Competences and that should privilege University Extension as a part of the formation, according to the Resolution #7/2018 of the CFE [4], that defined the understanding of University Extension for the higher education in Brazil, pointed the ways that extension can be done, and established that the amount of 10% of the total duration of the courses should be fulfilled with extension activities.

This paper reports the process of construction of a Curricular Referential for Extension Activities for Industrial Engineering Courses in Brazil.

2 University Extension

The first records about the University Extension Movement, reports that it emerged as an educational scheme raised in England during the 1870s, aiming to provide education for those unable to go to university (LAWRIE, 2014).

Already in the late 19th century, Roberts (1891) claimed that higher education needed opportunities larger than formal classes and working classes, and that in the University of Cambridge it was provided by university extension activities. The experience was followed by other important universities in the subsequent years (Oxford, Durham, and others).

In 1923, Draper (1923) presented an extent report about the practices of University Extension in England, highlighting that a wide field for development was still open and should be pursued.

Ludwig (1994) affirmed that extension systems seen in United States should be challenged to integrate international perspectives and to develop global competencies, and Berrio (2003) stated that extension activities should be used to achieve organizational cultures objectives.

In the case of Brazilian Higher Education, extension is supposed to be the activity that integrates the contents and components of the curriculum constituting an interdisciplinary process of interaction between higher education institutions and the other sectors of society, in permanent articulation with teaching and research (BRASIL, 2018).

An example of this integration, out of the engineering field, was reported by Costa et al (2020): Psychology students held workshops with adolescent students from a public elementary school, and working with themes that the adolescents requested, university extension was perceived as an important space for reflection on health education and health education, complementing professional training.

Saraiva (2007) addresses the benefits of university extension in the professional formation and in the expansion of knowledge derived by universities, highlighting that the university extension is a way to assure the mission of universities to educate citizens compromised with the development of a just society.

2.1 University Extension on Higher Education – literature review

The subject of university extension in the field of engineering is a subject that is still little explored in the literature. In a search carried out in the scopus database on May 31, 2023, using the expression "University Extension", limiting the results only to articles in the area of engineering, and in English, Portuguese and Spanish, only 15 results were found. After analyzing the documents, 5 documents were discarded, as they did not deal with extension courses within the scope of engineering courses.

The selected papers were classified into 4 groups. The first group is formed only by the article by Slotten (2008) that reports how university extension occurred during the 1920s, through the use of university radio.

The second group is made up of 5 papers that describe and analyze the impact on communities of university extension projects covering topics related to engineering. Buson and Ferreira (2004) reported the impact of an extension project by the University of Brasília (Brazil) in an impoverished community in the region. The report by Hsia, Shie and Chen (2008) presents the strategy of the Technological University of Chimkuo (Taiwan) in analyzing the impact of extension projects carried out by the university, through data mining, to improve actions related to university extension. Pereira, Luz and Ribeiro (2019) analyzed the impact of the project conducted by the Pontifical Catholic University (PUC) of Campinas (Brazil) to develop a central waste sorting pilot project in response to the requirements by a recycling cooperative. Sulaiman, Moura and Nogueira (2022) carried out an analysis of the impact of extension projects of the Federal University of ABC with regard to disaster risk reduction (DRR) in the region, and the importance of the results of these projects for decision-making by local stakeholders. Villegas (2022) analyzed the challenge of maintaining the ISO 9001:2015 standard in extension services provided by Central Luzon State University and Tarlac State University (USA).

The third group is related to 1 article that reports the impact of the extension project on the training of engineering students. Stefanelli-Silva et al (2019) reported that students who participated in the project related to ocean engineering with themes focused on marine biology at the Universidade Estadual Paulista – UNESP (Brazil) provided with the opportunity for an informal teaching environment complementary to their usual academic-centric degree, with a fresh perspective on accessible scientific communication.

The last group deals with 3 articles that deal with university extension as part of the curriculum. Mujani et al (2012) report the case of the National University of Malaysia, which created a Center for Educational Extension whose purpose is to provide the university with information to improve the courses offered. Ling (2017) describes the use of a questionnaire to interview the various people involved in extension projects, to improve engineering careers at the university. Yusuf et al (2021) report an interesting experience involving students in extension actions as part of their training, which has generated professionals who are better able to meet society's demand.

Despite the small number of publications, there is sufficient evidence that deals with the impact and the need to include extension in the training of better engineers and with effective action in society.

2.2 University Extension on the Brazilian Higher Education

According to the Resolution #7/2018 of the CFE, besides integrating the contents and components of the curriculum in a process of interaction between higher education institutions and the other sectors of society, extension can constitute an opportunity of dialogue with the society. Higher Education Institutions can bring more than knowledge to society, they can bring experiences that are not in the everyday life, and this is a chance to give a citizenship training of students, marked and constituted by the experience of applying their knowledge. There is also the opportunity to produce changes in the higher institution itself and in other sectors of society, based on the construction and application of knowledge, as well as through other academic and social activities (BRASIL, 2018). These initiatives must reflect in the social compromise of education institutions to build a better society.

Therefore, extension activities must involve external communities, and must also be directly related to the professional and citizenship formation of the student.

3 Methodology

The elaboration of the reference was carried out as follows: the ABEPRO Graduation Working Group, due to the challenges declared by the community in implementing the current regulations, assumed the commitment for the year 2022 to present an orientation material. Thus, studies about the regulations related to university extension in higher education and about the specialized literature on the subject were conducted. Additionally, the observation of successful experiences of university extension initiatives in engineering courses, especially Industrial Engineering, was carried out. Based on this accumulation of knowledge, a document entitled "...", was drawn up, which was later submitted for consideration, where it had minor adjustments, and approval by the ABEPRO community assembly.

4 Construction of a University Extension Referential

According to the literature and to the Resolution #7/2018, university extension activities can be included in the following modalities:

- Programs;
- Projects;
- Specific courses and workshops;
- Events;
- Services provision.

In all of these modalities, the activities must provide interventions in one or more sectors of the society, resulting in intellectual and practical gain for students and transmission of knowledge to the affected community at the very least. The interventions can have different characteristics:

- Educational Interventions, that are carried out with Social or Business Organizations;
- Productive Interventions, that are carried out with Social Organizations (hospitals, orphanages, NGOs, etc.);
- Improvement and Optimization Interventions, that are carried out in Business Environments, with emphasis on small and medium-sized companies;
- Development and Innovation Interventions, that are carried out with Business Organizations, Startups and Incubators.

The Forum of Provosts of Extension of Brazilian Universities (FORPROEX) defined that the activities of extension can happen in 5 different areas:

- Communication;
- Culture;
- Human Rights and Justice;
- Education;
- Environment;
- Health;
- Technology and Production;
- Work.

Finally, FORPROEX listed 53 possible lines for the development of extension activities, from which are highlighted those 23 most related to engineering areas (but it does not exclude others):

1. Product development;
2. Regional development;
3. Rural development and agrarian issues;
4. Technological development;
5. Urban development;
6. Professional education;
7. Entrepreneurship;
8. Employment and income;
9. Scientific and technological diffusion;
10. Teachers and educator's formation;
11. Job management;
12. Informational management;
13. Institutional management;

14. Public management;
15. Technological innovation;
16. Teaching methodologies;
17. Patents and intellectual properties;
18. Environmental issues;
19. Water resources;
20. Solid waste;
21. Health and Protection at Work;
22. Information Technology;
23. Human development.

Finally, it is important to point out some pillars of an activity of extension:

- The student is the protagonist in the formation of skills developed by the extension activity;
- There must exist supervision and teaching guidance, in order to guarantee the formation of the competences proposed by the activity;
- The activity must be performed outside the HEI, preferentially in the community in which it operates;
- The activity must have impact on the external community, and its result must be evaluated, measured, documented and, whenever possible, communicated and shared with society.

4.1 How to carry out extension activities

Activities of extension can be carried out in different ways, and some are described below.

1. An integrative project, involving students and an organization (manufacturing or service organization), can be proposed as a single curricular component (discipline) or integrating two or more curricular component. In the case of a project of single discipline, the knowledge can be carried to the organization by means of a course or through a consultancy (machining, production or any other intervention). And in the case of a project that integrates two or more disciplines, there can exist a theme and an application in the organization that will involve knowledge of the participants components.
   Here, it is possible to determine an amount of hours that the curricular component (or components) will credit as extension.
2. A more embracing thematic project, with vertical integration of components inside the course, or with inter and transdisciplinary integration. Also, it can happen inside the course, as an integrated action of all disciplines of the therm.
   Here, the number of hours dedicated to the project can be credited to the disciplines directly or as complementary activities (does not compose the component load).
3. As an institutional specific project, that happens not in a curricular component, but as the integration of various courses focused on a specific theme. The institution can sign a deal with an organization aiming the development of the project, and the extension activity will be credited as complementary activity.
4. As a part of an institutional program, more embracing and aligned with institutional policies (e.g.: planning the maintenance of equipment of a university hospital).
5. Formalized as a service provision of the institution to organizations, with specific scope and deadline. In this case, the student takes part of the service provision as a junior consultant, and the hours will be credited as complementary activity.

6. Offering courses and workshops to the community. The courses can focus on professional development or actualization, and the workshops can develop abilities of members of the community.
7. Take part of events like conferences, shows or any other kind of manifestation. The student can participate as a listener or as organizer, each one with different number of hours to be credited as complementary activity.

To organize and control the activities, a sheet is proposed as follows (Table 1).

Table 1. Proposed control table for extension activities.

Name of activity: <name of activity>; <hours>			**Area: <area of extension>**	
Characteristic / Line(s)	**Educational**	**Productive**	**Improvement and Optimization**	**Innovation and Development**
1 23	**<description>**			

As an example, an integrative project developed by two curricular components joint to an organization could be described like shows Table 2 and Table 3.

Table 2. Example #1 of control for extension activities.

Name of activity: Lean applied to aluminum smelter furnace loading; 10 hours			**Area: Technology and Production**	
Characteristic / Lines	**Educational**	**Productive**	**Improvement and Optimization**	**Innovation and Development**
4; 15			Apply Lean concepts to the loading area of an aluminum smelter furnace	

Table 3. Example #2 of control for extension activities.

Name of activity: Smart Cities; 15 hours			**Area: Environment**	
Characteristic / Lines	**Educational**	**Productive**	**Improvement and Optimization**	**Innovation and Development**
2; 7; 14; 18				New destinations for industrial waste in plastic manufacturing

5 Final Considerations

This study aimed to present the result of the construction of a reference for teams of directors of undergraduate industrial engineering courses regarding the introduction of extension as a complement to student training. It is hoped that this reference can fill the gap of guidance to directors of what has been defined as guidelines for the new curricula. In addition to complying with regulations, it is expected that this framework will contribute to the training of industrial engineers who are more involved with the community, delivering more qualified professionals to society in broad terms.

6 References

Berrio, A. A. (2003). An Organizational Culture Assessment Using the Competing Values Framework: A Profile of Ohio State University Extension. The Journal of Extension, 41(2), Article 4.

Brasil: *Law of Education Guidelines and Bases* - Law 9394/1996. Federal Law. (1996).

Brasil: Resolution #11/2002 - *Guidelines for Engineering Courses*. Federal Council of Education (CFE), Brasilia - BR (2002).

Brasil: Resolution #2/2019 - *Guidelines for Engineering Courses*. Federal Council of Education (CFE) , Brasilia - BR (2019).

Brasil: Resolution #7/2018 – *Establishes the Guidelines for Extension in Brazilian Higher Education.* Federal Council of Education (CFE) , Brasilia - BR (2018).

Buson, M. A., & Ferreira, O. L. (2004). "Varjão" - dwelling and citizenship together an extension project at the university of brasilia. *International Journal for Housing Science and its Applications, 28*(1), 21-31.

Christie, M., & de Graaff, E. (2017). The philosophical and pedagogical underpinnings of Active Learning in Engineering Education. *European Journal of Engineering Education, 42*(1), 5-16. doi:10.1080/03043797.2016.1254160

Costa, A. C. de P. da, Aragão, T. A. P., Pereira, C. S., Nogueira, F. J. de S., Rodrigues, M. G., Filho, C. R. C., Ventura, C. Angelo; Figueiredo, E. B. G. (2020). Educação e Saúde: a extensão universitária como espaço para tencionar e pensar a educação em saúde / Education and Health: university extension as a space to intend and think about Health education. *Brazilian Journal of Development*, 6(4), 21616–21630. https://doi.org/10.34117/bjdv6n4-362

Disponível em: https://books.google.com.br/books?hl=pt-BR&lr=&id=yJVJAAAAIAAJ&oi=fnd&pg=PA1&dq=%22university+extension%22&ots=9bPLDrvlaj&sig=VfH-ofDtTq51ci5dLlzYYTZgfJI&redir_esc=y#v=onepage&q=%22university%20extension%22&f=false (acesso em 31/01/2023)

Draper, W. H. *University Extension: A Survey of Fifty Years*, 1873-1923. Cambridge: At the University Press. Disponível em: https://books.google.com.br/books?hl=pt-BR&lr=&id=TEc9AAAAIAAJ&oi=fnd&pg=PA32&dq=%22university+extension%22&ots=70ERSoq5dZ&sig=6fw_88SzB0H80Q2IS8HUVnoRqDo&redir_esc=y#v=onepage&q=%22university%20extension%22&f=false (acesso em 31/01/2023)

Edström, K., & Kolmos, A. (2014). PBL and CDIO: complementary models for engineering education development. *European Journal of Engineering Education, 39*(5), 539-555. doi:10.1080/03043797.2014.895703

Graaff, E. d., & Kolmos, A. (2003). Characteristics of Problem–Based Learning. *International Journal of Engineering Education, 19*(5), 657-662.

Graaff, E. d., & Kolmos, A. (Eds.). (2007). *Management of Change: Implementation of Problem-Based and Project-Based Learning in Engineering*. Roterdam: Sense Publishers.

Helle, L., Tynjälä, P., & Olkinuora, E. (2006). Project-Based Learning in Post-Secondary Education - Theory, Practice and Rubber Sling Shots. *Higher Education, 51*(2), 287-314.

Hsia, T. -., Shie, A. -., & Chen, L. -. (2008). Course planning of extension education to meet market demand by using data mining techniques - an example of chinkuo technology university in taiwan. *Expert Systems with Applications, 34*(1), 596-602. doi:10.1016/j.eswa.2006.09.025.

Lawrie, A. (2014). The University Extension Movement. In: *The Beginnings of University English*. Palgrave Macmillan, London. https://doi.org/10.1057/9781137309112_4

Lima, R. M., Andersson, P. H., & Saalman, E. (2017). Active Learning in Engineering Education: a (re)introduction. *European Journal of Engineering Education, 42*(1), 1-4. doi:10.1080/03043797.2016.1254161

Lima, R. M., Dinis-Carvalho, J., Flores, M. A., & Hattum-Janssen, N. v. (2007). A case study on project led education in engineering: students' and teachers' perceptions. *European Journal of Engineering Education, 32*(3), 337 - 347.

Ling, L. (2017). Pluralistic extension analysis model of talent cultivation reform in colleges and universities. *Agro Food Industry Hi-Tech, 28*(1), 778-782.

Ludwig, B. G. *Internationalizing extension: An exploration of the characteristics evident in a state university extension system that achieves internationalization*. The Ohio State University, ProQuest Dissertations Publishing, 1994. 9420985.

Mujani, W. K., Hamid, M. A., Ya'akub, N. I., Din, L., Hussain, W. M. H. W., Jamsari, E. A., . . . Ashari, M. Z. A. H. (2012). Strategic planning of centre for educational extension (PKP) for key performance index enhancement of national university of malaysia (UKM) as a research university. Advances in Natural and Applied Sciences, 6(3 SPECL.ISSUE 2), 299-302.

Pereira, R., Luz, V., & Ribeiro, D. (2019). An experience with university outreach: A project for a solid waste recycling cooperative. [Una experiencia de extensión universitaria: Proyecto para cooperativa de reciclaje de residuos sólidos] *AUS, 25*(2019), 53-61. doi:10.4206/aus.2019.n25-09.

Powell, P. C., & Weenk, W. (2003). *Project-Led Engineering Education*. Utrecht: Lemma.

Roberts, R. D. *Eighteen Years of University Extension*. Cambridge: at the Univerity Press.

Saraiva, J. L. Papel da extensão universitária na formação de estudantes e professores / Role of the university extension in the student and teacher formation. *Brasília méd* ; 44(3): 225-233, 2007.

Slotten, H. R. (2008). Radio's hidden voice: Noncommercial broadcasting, extension education, and state universities during the 1920s. *Technology and Culture, 49*(1), 1-20. doi:10.1353/tech.2008.0049.

Stefanelli-Silva, G., Pardo, J. C. F., Paixão, P., & Costa, T. M. (2019). University extension and informal education: Useful tools for bottom-up ocean and coastal literacy of primary school children in brazil. *Frontiers in Marine Science, 6*(JUL) doi:10.3389/fmars.2019.00389.

Sulaiman, S. N., Moura, R. B., & Nogueira, F. R. (2022). From geotechnics to participatory management: A critical analysis of university extension projects with a focus on disaster risk reduction. [Da geotecnia para a gestão participativa: uma análise crítica de projetos de extensão universitária com foco na redução de risco de desastre] *Urbe, 14* doi:10.1590/2175-3369.014.e20210118.

Villegas, M. N. (2022). Analysis of the implementation of ISO 9001:2015 in extension services of the state universities and colleges in region III using multivariate linear regression. *International Journal of Applied Engineering and Technology (London), 4*(1), 77-85.

Yusuf, S. F. G., Nesengani, T., Popoola, O. O., & Gwala, L. (2021). Promoting university–community alliances in the experiential learning activities of agricultural extension postgraduate students at the university of fort hare, south africa. *Sustainability (Switzerland), 13*(18) doi:10.3390/su131810411.

People Competence Assessment Based on Project Management Scenarios

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Abstract

Scenario-based assessment makes it possible to represent situations related to professional project management practices and, in this sense, allows the assessment of competences in contexts inspired by professional environments. From the point of view of project management competences, the Individual Competences Baseline (ICB) describes the competences required for individuals who work in the field. This framework shows, besides other competences, the 10 (ten) competences focused on people, namely: introspection and personal management; personal integrity and reliability; personal communication; leadership; teamwork; relationships and engagement; resourcefulness; conflict and crisis; negotiation and results orientation. This study aims to analyze the process of assessment of competences based on Project Management scenarios, in the context of the Engineering field. This study was based on an experimental process and involved Professors and Professionals in the Project Management area. As a result, an assessment of competences was obtained through dynamic, interactive scenarios, which promotes reflection and is aligned with professional project management practices. Another result points to the potentiality of applying scenarios, as a complementary strategy to traditional assessments. For future work, it is suggested to develop scenarios that can assess the other competences required by individuals who work in project management.

Keywords: Competence Assessment; Competences focused on People; Scenarios; Project Management.

1 Introduction

The field of project management is evolving: old methods undergo modifications, new tools are created, and researchers propose new points of view in their studies (Wawak & Woźniak, 2020). Although the area of project management is relatively recent (Kerzner, 2009), its importance has been growing continuously in recent years (Wawak & Woźniak, 2020) and, consequently, the profession of project management follows this growth and permanent changes (IPMA, 2015).

Several methods and techniques have been developed covering all aspects of a project, from its conception to the final delivery (Patah & de Carvalho, 2012). Despite this, few assessment methods address project management competences. Process-oriented standards mainly prescribe procedures and methods; whereas competence-oriented standards present a broad spectrum of knowledge and competences required for successful performance (Vukomanović, Young, & Huynink, 2016).

The International Project Management Association (IPMA) has developed a global framework that defines the competences required by individuals working in the field of project, programme and portfolio management, named the Individual Competence Baseline (ICB) (IPMA, 2015). The Individual Competence Baseline show the division of the classification of competences into three domains: competences focused on the perspective, which respond to the context of projects; competences focused on people, which respond to personal and social topics; and the competences focused on practices, which respond to the specific practices of project management (IPMA, 2015). The definition of the term competence, according to IPMA (2015) refers to the demonstration of competence as the application of knowledge, skills and abilities to achieve the desired results.

From the perspective of competences focused on people, organizations that group and/or select people with the appropriate profile in teams to solve tasks/activities will have better chances of remaining in the market, and creating value for customers when compared to organizations that do not apply or consider this "approach" (Scott-Young & Samson, 2008). Competences act as a differentiating factor in performance, and the fact that competence management is a feature in which organizations have been investing is not a casualty, however, a competence assessment process is required.

According to Tinoco, Lima, Mesquita, and Souza (2022), the most common assessment methods focused mainly on the theoretical aspect of knowledge do not seem to be sufficient to prepare professionals for professional practice. In this case, it emerges the need to present alternative approaches capable of preparing the professional of project management more effectively for the challenges of the job.

In methods of assessing competences in areas related to Health and Education, one of the approaches used is the assessment of competences based on scenarios (Hagler & Wilson, 2013; Kennedy, Regehr, Baker, & Lingard, 2008; Redfern, Norman, Caiman, Watson, & Murrells, 2002; Van Der Vleuten & Schuwirth, 2005). The scenarios are structured in situations inspired by professional practice. The situations allow professionals to respond to challenges supported by their competences, and to be assessed according to the situation with which they are being confronted (Tinoco et al., 2022; Wroe et al., 2017).

According to Hagler and Wilson (2013), no studies present guidelines for the development and use of scenarios in assessment processes. Despite this scarcity of research, it is possible to state that the assessment of competences based on scenarios requires the consideration of at least three key elements: (1) Competences, which reflect the behaviour to be assessed; (2) Instrument to support the assessment; and (3) Scenario, which provides the context for the assessment (O'Brien, Hagler, & Thompson, 2015). Within this framework, for competence to be assessed, it is necessary to plan the assessment and develop an instrument that supports the process (Hagler & Wilson, 2013). Rubrics are important instruments in assessment processes (Arcuria, Morgan, & Fikes, 2019) as they establish criteria and levels through a rating scale (Shipman, Roa, Hooten, & Wang, 2012). The use of rubrics, therefore, allows for an assessment based on criteria previously due and developed according to the context of the assessment. Thus, the study’s overall objective is to analyze the process of assessment of competences based on Project Management scenarios, in the context of the Engineering field.

2 Background

2.1 Individual Competence Baseline (ICB)

The framework describes a set of competence elements for individuals working in Project, Programme and Portfolio Management. The design of the framework was developed by the International Project Management Association (IPMA). The model has become a reference focusing on the individual who works on Projects, Programs and Portfolios. According to Vukomanović et al. (2016), this model excels in enriching and enhancing individual competences and providing an inventory of competences that, if fully observed, represents a complete knowledge of these management domains.

Each individual must have competences focused on perspectives, which respond to the context of projects, competences focused on people, which respond to personal and social topics, and competences focused on practices, which respond to the specific practices of project management (IPMA, 2015). Thus, the model developed for project management contemplates, in total, twenty-eight competences, as well as Table 2.

Table 1. ICB Individual Project Management Competence IPMA (2015).

PRACTICE COMPETENCES (14)	PEOPLE COMPETENCES (10)	PERSPECTIVE COMPETENCES (5)
Project design	Self-reflection and self-management	Strategy
Requirements and objectives	Personal integrity and reliability	Governance, structures and processes
Scope	Personal communication	Compliance, standards and regulation
Time	Relationships and engagement	Power and interest
Organisation and information	Leadership	Culture and values
Quality	Teamwork	
Finance	Conflict and crisis	
Resources	Resourcefulness	
Procurement	Negotiation	
Plan and control	Results orientation	
Risk and opportunity		
Stakeholders		
Change and transformation		
Selection and balancing		

Without disregarding all types of competence, the decision was made for this study to analyze and select the subset of competences focused on people. This option is related to the fact that such competences are the least studied in the area of Engineering Project Management and have a high level of relationship with the way they become effective in other competences. Moreover, people have high importance and contribution to the success of projects.

2.2 Assessement of Competences

The assessment of competences transcends the disciplinary areas and its research has increased worldwide (Souza & Lima, 2020). The assessment of competences in the universe of Engineering is something relatively new when compared to other disciplinary areas, namely Medicine and Education. The assessment of competence arose from growing criticism of traditional testing; methods related to the unrealistic nature of tests. As a consequence, there was a "loss of faith" in valid learning measures (McDowell, 1995).

Scenario-Based Assessment is a form of assessment and learning that has been established for over 50 years and has grown in practice. Scenarios represent any activity that can exemplify particular issues and situations at work (Carrol, 1999). Scenarios are, the starting point for individuals to immerse themselves in a real-world problem, developing a subsequent solution-finding process. During this process, they must apply their individual knowledge and cognitive and social competences to solve problems collaboratively (Erol, Jäger, Hold, Ott, & Sihn, 2016). In this case, the difference from traditional assessment methods to a scenario-based assessment is represented in the practical component and inspired by real-world problem.

In addition to the assessment approach, according to Marinho-Araujo and Rabelo (2015), it is necessary to develop assessment tools that show how the articulation between theory and practice occurs and propose assessment indicators that highlight the competences. In this sense, considered as an assessment instrument, rubrics establish criteria and levels through a rating scale and can offer a more equitable and consistent assessment, thus avoiding subjectivity (Shipman et al., 2012). Moreover, rubrics are characterized as a differentiated assessment instrument compared to traditional educational assessment instruments, such as written tests, by integrating assessment criteria associated with professional practices (Souza, Margalho, Lima, Mesquita, & Costa, 2022).

3 Methodology

This study aims to analyze ten scenarios and rubrics for competences assessment, focused on people, of Project Management, and in this way, it was defined as an Assessment Model for Project Management People Competences.

For the development of scenarios, the six steps defined in Souza, Lima, Mesquita, and Margalho (2022) served as a reference and the study of Souza, Margalho, et al. (2022) for the development of the rubrics for evaluation. The model, in addition to scenarios and rubrics, presents procedures and information for the evaluation. This includes the objectives, instructions and background. Evaluated participants do not have the evaluation rubric in advance. The evaluation criteria included in the rubric are well-known indicators in the area of project management.

Each scenario in the model assesses a competence focused on people and includes a rubric for assessment. Regarding objectives, each competence relies on the definition of some key objectives. These objectives are associated with the rubric for evaluation and, therefore, are the evaluative criteria, more specifically, the key indicators of the IPMA (2015). The template presents the instructions for the evaluator in a standardised way for all scenarios. Appendix A presents a scenario and rubric for assessment of the Personal Communication Competence.

As for the experimental process to evaluate the model, it was carried out on May 2022 and involved the participation of 49 people. The following participated in the application: twenty evaluators; ten evaluated participants; twelve observers; two trained personages; two consultants and three people from the support team. For the assessment process, ten classrooms were organised, called stations, in which one people-focused project management competence was assessed per room. At each station, there were two evaluators, one with an academic profile and the other with a professional profile. At the door of each station, the scenario to assess competence was fixed. Each participant evaluated had two minutes to read and understand the scenario and, after a beep, could enter the room. The response time for each scenario was eight minutes. At the end of the time, the sound signal rang again, informing the end of the time for the evaluation process at each station. Immediately, the participant moved to the next station. The evaluation process was continuous and intermittent, ending when the participants had passed through all the stations.

For data collection, questionnaire surveys were carried out and participants were asked to answer a set of open questions and a closed question following an established order. To analyze the results, the content analysis technique was used as the data collected were systematised based on this technique (Bardin, 1977).

4 Results

The results of this study emerge in the identification of the benefits and applicability of the evaluation model, based on Engineering scenarios.

4.1 Benefits of Scenario-Based Competence Assessment

With the application of the model, we sought to assess the benefits based on the study participants (evaluators, evaluated participants and observers). To analyze the results of the benefits, Table 2 presents the results collected based on the measure of the frequency of the list of benefits, identified in the literature. The most representative benefits mentioned by the groups were namely: dynamic and interactive evaluation process; promotion of creativity and self-knowledge; and alignment with professional project management practices.

Table 2. Benefits of the Competences Assessment Model.

Benefits	Evaluators (n=20)	Evaluated (n=10)	Observers (n=12)
	Frequency (f)	Frequency (f)	Frequency (f)
Dynamic and interactive	**13**	**10**	6
Diversified and representative	8	2	1
Visual and practical	10	2	1
Explains reasoning in an open manner	11	6	**7**
Mobilisation of competences	11	3	5
Assertive assessment	1		3
Aligned with professional practices	**12**	6	6
Promotes reflection and self-knowledge	**15**	**8**	**12**
Encourages creativity compared to other assessment tests	**12**	**8**	**9**

According to the observers, the alignment of the scenarios with Project Management Professional Practices was identified as an excellent contribution of the model:

"Very realistic and meets the reality in the labour market." (Fixed Observer 1)

" (...) this method brings participants into real professional life." (Fixed Observer 8)

" (...) it portrays situations that happen frequently in the world of work, from conflicts between team members to delays in projects." (Fixed Observer 2)

Furthermore, mobilising resources to face/respond to a real-life scenario provokes the participant to self-reflect on their performance, as highlighted by the evaluators:

"I think one of the benefits is that it is an individual exercise, allowing the participant to have a self-perception of the competences associated with the scenario in real-time, considering their own performance, insofar as it is also a context close to the real context." (Evaluator 16)

"(...) allows for the analysis of personality traits, self-reflection and analysis from different perspectives of the same problem. (Evaluator 28)

Concerning spontaneity and creativity to respond to the situations presented in the scenario, the participants state that:

"(...) promotes the spontaneity and creativity of the people being assessed. (Participant 7)

" (...) more valid and spontaneous way because the answers are not studied or decorated." (Participant 6)

" (...) it forces you to work creatively." (Participant 7)

In addition, evaluators highlighted as an assessment process that manages to obtain answers from the professional without provoking or causing embarrassment and also promotes the participants' power of synthesis:

"It is a process that manages indirectly to get answers without having to cause embarrassment to the interviewee." (Evaluator 21)

"It makes the appraisee more comfortable to speak because it is about opinions to a third party. It's great because most people would find it very difficult to talk about themselves." (Evaluator 22)

4.2 Potential Applicability of the Scenario-Based Competence Assessment

The study findings concerning the applicability of the competence assessment model were evidenced, for example, by Participant 2 statement:

> "The potential of using scenario-based assessment is huge. After going through the experience, it is funny to realise how extensive it is and the wide spectrum of applications. It forced me to reflect and 'dig' into perhaps more lost and not-so-present capacities that should be harnessed." (Participant 2)

Other potential applications of the scenario-based competences assessment can be identified in the data, namely:

For professional recruitment processes:

> " (...) it could be an added value in selective processes, just like the dynamics of selective processes." (Evaluator 23)

> " (...) whether with traditional corporate recruitment methods where we already know that there is always the typical question "Where do you see yourself in 5 years?" and "What are your two best qualities and defects?" or "Tell me a bit about yourself". This method highlights the genuineness of the answers and in my opinion will end up being very useful." (Participant 6)

For team acquisition or selection:

> ''(...) for example, in my first teams, the choices of the elements fell a lot on the person's technique, and what he or she could do, with the gain of experience I started to opt more for personalities, so I think this process fits here, more than knowing if the person is good technically, we should look for a personality that fits the project.'' (Evaluator 29)

For training processes in team building actions, coaching, in addition to teacher training for the area of Education.

> " (...) is transferable to different areas of knowledge. By way of example: in the area of Education it could be something carried out in teacher training." (Evaluator 16)

> " (...) it can be applied in team buildings in companies, in the sense of training." (Evaluator 14)

In the academic field:

> " (...) the use of this type of assessment at the academic level (and beyond) better prepares students for the real world." (Participant 1)

> "In pedagogical terms, it seems to me that there is a lot of potential to empower students with some competences, which are highly valued by companies, but hardly teachable." (Evaluator 12)

Finally, the results show a higher contribution assessment approach when compared to traditional assessment models:

> " (...) the creation of this assessment method proved to be more efficient and interesting compared to a traditional test (...)." (Participant 1)

> " (...) major differences between this model and assessment tests lies in the practical component that the scenario model has." (Fixed Observer 2)

> " (...) I perceive its value as a complement to a traditional assessment, to assess skills that are not normally assessed." (Participant 9)

Learning with this type of assessment model, based on scenarios is an added value if compared to so-called traditional assessment models:

> " (...) I learned much more than if the assessment was based on normal assessment tests." (Fixed Observer 2)

5 Conclusion

The scenario-based competence assessment process provided participants with moments of learning and development of their competences. Such a conclusion is based on the need to mobilise the resources, knowledge and abilities they need to interact with the different scenarios. This process enabled great contributions of the assessment model competence to be evidenced as an excellent model for learning and developing project management competences.

The main benefits verified are the identification of a dynamic and interactive assessment process, which promotes creativity and self-reflection, providing alignment with the professional practices of project management. Besides providing the assessment based on scenarios, quite interesting and enriching when compared to traditional assessment methods that are less integrated and tend to quantify in a less effective way the presence and even the metrics of the competence assessed.

The perception of assurance of success and quality of the competences assessment model implied ensuring its potentiality as an assessment model with contributions for organizations, certifying agencies, and individuals benefited with new and better ways of assessment and certification of competences of engineering project management. Furthermore, the model was evaluated by professionals as an excellent method of evaluation, allowing the selection of the professional for the intended function taking into account the competences essential for the success of the project. For certifying agencies, a scenario-based assessment process allows the individual to mobilise competences that they are often unable to demonstrate and/or mobilise in traditional methods. The assessment model generates motivation and enthusiasm and allows creativity to be explored.

The assessment model competence in engineering project management represents an innovation for the professional field with several potential applications, namely in recruitment processes, team acquisition, and training, in the academic field and replaces and/or complements traditional assessments. In addition to this, the absence of scenario-based assessment models within the professional scope was confirmed and the evaluators, evaluated and observers highlighted the fact that they had never participated in a scenario-based assessment process throughout their professional career.

Therefore, it can be concluded that the scenario-based model for the assessment of project management competences is an innovative way to the assessment of competences, focused on people, of project management.

6 References

Arcuria, P., Morgan, W., & Fikes, T. (2019, March 2019). Validating the use of LMS-derived rubric structural features to facilitate automated measurement of rubric quality. Paper presented at the Proceedings of the 9th International Conference on Learning Analytics & Knowledge, New York, NY, United States.

Bardin, L. (1977). Análise de conteúdo. Lisboa: edições, 70, 225.

Carrol, J. M. (1999). Five reasons for scenario-based design. Paper presented at the Proceedings of the 32nd Annual Hawaii International Conference on Systems Sciences. 1999. HICSS-32. Abstracts and CD-ROM of Full Papers.

Erol, S., Jäger, A., Hold, P., Ott, K., & Sihn, W. (2016). Tangible Industry 4.0: a scenario-based approach to learning for the future of production. Procedia CiRp, 54, 13-18.

Hagler, D., & Wilson, R. (2013). Designing nursing staff competency assessment using simulation. Journal of Radiology Nursing, 32(4), 165-169.

IPMA. (2015). Individual Competence Baseline for Project, Programme & Portfolio Management. In International Project Management Association (Vol. 4). https://www.ipma.world/.
Kennedy, T. J., Regehr, G., Baker, G. R., & Lingard, L. (2008). Point-of-care assessment of medical trainee competence for independent clinical work. Academic Medicine, 83(10), S89-S92.
Kerzner, H. (2009). Project management: A systems approach to planning. Scheduling, and Controlling, Volume 7.
Marinho-Araujo, C., & Rabelo, M. (2015). Avaliação educacional: a abordagem por competências. Avaliação: Revista da Avaliação da Educação Superior (Campinas), 20, 443-466.
McDowell, L. (1995). The impact of innovative assessment on student learning. Innovations in Education and Training International, 32(4), 302-313.
O'Brien, J. E., Hagler, D., & Thompson, M. S. (2015). Designing simulation scenarios to support performance assessment validity. The Journal of Continuing Education in Nursing, 46(11), 492-498.
Patah, L. A., & de Carvalho, M. M. (2012). Métodos de gestão de projetos e sucesso dos projetos: um estudo quantitativo do relacionamento entre estes conceitos. Revista de Gestão e Projetos, 3(2), 178-206.
Redfern, S., Norman, I., Caiman, L., Watson, R., & Murrells, T. (2002). Assessing competence to practise in nursing: A review of the literature. Research Papers in Education, 17(1), 51-77. doi:10.1080/02671520110058714
Scott-Young, C., & Samson, D. (2008). Project success and project team management: Evidence from capital projects in the process industries. Journal of Operations Management, 26(6), 749-766.
Shipman, D., Roa, M., Hooten, J., & Wang, Z. (2012). Using the analytic rubric as an evaluation tool in nursing education: the positive and the negative. Nurse Education Today, 32(3), 246-249.
Souza, M., Lima, R., Mesquita, D., & Margalho, E. (2022). Development and Validation of Scenarios for the assessment of Project Management People Competences. Paper presented at the International Symposium on Project Approaches in Engineering Education.
Souza, M., & Lima, R. M. (2020). An overview of the assessment of competences based on publications in journals. Paper presented at the International Symposium on Project Approaches in Engineering Education.
Souza, M., Margalho, E., Lima, R., Mesquita, D., & Costa, M. J. (2022). Rubric's Development Process for Assessment of Project Management Competences. Education Sciences, 12(12), 902. doi:https://doi.org/10.3390/educsci12120902
Tinoco, E., Lima, R., Mesquita, D., & Souza, M. (2022). Using scenarios for the development of personal communication competence in project management International Journal Project Organisation and Management.
Van Der Vleuten, C., & Schuwirth, L. (2005). Assessing professional competence: from methods to programmes. Medical Education, 39(3), 309-317.
Vukomanović, M., Young, M., & Huynink, S. (2016). IPMA ICB 4.0—A global standard for project, programme and portfolio management competences. International journal of project management, 34(8), 1703-1705.
Wawak, S., & Woźniak, K. (2020). Evolution of project management studies in the XXI century. International Journal of Managing Projects in Business.
Wroe, E., McBain, R., Michaelis, A., Dunbar, E., Hirschhorn, L., & Cancedda, C. (2017). A novel scenario-based interview tool to evaluate nontechnical skills and competencies in global health delivery. Journal of graduate medical education, 9(4), 467-472.

Appendix A - Sample Scenario and Rubric for Assessing Personal Communication Competence

TITLE: ONE STEP AT A TIME

The project manager of the development of a new line of sports shoes started a meeting by asking each team member to report on the activities developed in the previous week, according to the planning.
The employee Duarte, assigned to develop the new brand logo design, reported that he had sent the material to the marketing department for dissemination. He also mentioned that the version sent included the numerous changes and modifications made by the design team. Duarte explained to the project manager that, after numerous unsuccessful attempts through the project communication channel (e-mail) with the person responsible for validation/approval, he had to take such a decision to minimise delays that would harm the project. In his opinion, the version sent was in accordance with what was expected from the design project.
The project manager didn't let Duarte finish his speech and loudly shouted to the whole team the lack of responsibility and commitment of Duarte, by sending an activity without approval, and the damage that could cause to the project. He stressed that he had already mentioned that in situations like this, it would be necessary to attend and consider the procedures established in the communication plan. Imagine that the CEO of your company identified these symptoms in this particular team and decides to talk to the project manager, in this case, YOU.
Talk to the CEO of your company about the essential aspects of personal communication in Project Management and its importance for the project to be successful.
CHARACTER: YES / CEO OF THE ORGANISATION

PURPOSE OF THE STATION

This station aims to assess the participant's ability to mobilize personal communication arguments. The following are some key indicators that the participant will be able to demonstrate:
i) Provide clear and structured information to others and check their understanding.

ii) Facilitate and promote open communication.
iii) Choosing the style and channels of communication to meet the needs of the audience, the situation and the level of management.
iv) Communicate effectively with virtual teams.
v) Use humour and relativisation where appropriate.
When assessing the participant, consider the following instructions. View them as guidelines only.

INSTRUCTIONS FOR THE EVALUATOR
a) Make sure the participant has read and understood the scenario.
b) Cue the participant to start.
c) Immediately, the character starts the dialogue. The character (CEO of the organization) is trained to have a harsh and indignant attitude towards the failure of communication in a large and important project for the organization. He will intervene in the first 2 minutes of the evaluation and then ask for the participant's opinion on aspects of good communication.
d) Consider, in the participant's performance, the interaction with the character.
e) Answer "don't know" if the participant asks if you know something or if you like something or if you ask for their opinion.
f) Act in a standard way for all participants. The evaluator should give the participant as much space as possible so that they can present their perspective. Let the participant finish his/her line of argument, without interrupting him/her.
g) Ask questions linked to competence in case the participant starts repeating himself or blocking. Some examples of questions are: Have you been through a situation similar to this one, either as a leader or as a team member? If so, what actions have you taken that you think might be helpful for this scenario? What can we do to promote good communication in projects?
a) Develop further questions related to this competence if you identify that it is necessary.

INSTRUCTIONS FOR THE CHARACTER
a) After the participant enters the room, the character starts the dialogue.
b) The character must present a harsh and indignant attitude towards the communication failure in a large and important project of his company, only in the first 2 minutes of the evaluation. Afterwards, he/she will ask the participant's opinion on aspects of good communication, and the failed act of project management.
c) The character should act in a standard way for all participants. You should give the participant as much space as possible so that he can expose his perspective. Let the participant finish his line of argument, without interrupting him.
d) If the participant starts repeating himself or blocking you can ask questions linked to the competence. Some examples of questions are
Can personal communication benefit the management of a project? This week, I was reading a book by a recognized author in Project Management, Harold Kerzner, and I observed the following statement: "In a project environment, a project manager may well spend 90% or more of his or her time communicating." How do you interpret this statement?
e) The character, if necessary, can develop further questions linked to this competence.
The participant has 8 minutes to be interviewed. After the 8 minutes, you will hear a beep, and the evaluator will have 2 minutes to complete the evaluation rubric. Do not give feedback to participants.
BACKGROUND
Personal communication includes the exchange of information that is correct, accurate and presented consistently. The purpose of this skill is to enable an individual to communicate effectively and efficiently in a variety of situations, to different audiences and across cultures.
Personal communication describes the essential aspects of effective communication. Both the content and the medium of communication (tone of voice, channel and amount of information) must be clear and appropriate for the target audience. The individual has to check the understanding of the messages being conveyed by active listening and seeking feedback. The individual promotes open and sincere communication and masters various types of communication (presentations, meetings, memos, etc.), recognizing their value and limitations.

RUBRIC FOR EVALUATION
When evaluating the participant, consider the following rubric for evaluation. The measures considered most aligned with the current scenario have been highlighted, but the evaluated may demonstrate other measures depending on how they explore the scenario

RUBRIC FOR EVALUATION - PERSONAL COMMUNICATION
NAME EVALUATOR: PARTICIPANT Nº:

	Weight (1)	Weight (2)	Weight (3)	Weight (4)	Weight (5)

Key Indicators	The demonstration of this indicator and its measures is inadequate.	The demonstration of this indicator and its measures is low than expected.	The demonstration of this indicator and its measures is reasonable.	The demonstration of this indicator and its measures is good.	The demonstration of this indicator and its measures is excellent.
I1 - Provide clear and structured information to others and verify their understanding					
I2 - Facilitate and promote open communication					
I3 - Choose communication styles and channels to meet the needs of the audience, situation and management level					
I4 - Communicate effectively with virtual teams					
I5 - Employ humour and sense of perspective when appropriate					

I1 - Provide clear and structured information to others and verify their understanding: 1.1 Structures information logically depending on the audience and the situation; 1.2 Considers using story-telling when appropriate; 1.3 Uses language that is easy to understand; 1.4 Leverages public speaking and presentations; 1.5 Coaches and gives training; 1.6 Leads and facilitates meetings; 1.7 Uses visualisation, body language and intonation to support and emphasise messages.

I2 - Facilitate and promote open communication: 2.1 Creates an open and respectful atmosphere; 2.2 Listens actively and patiently by confirming what has been heard, re-stating or paraphrasing the speaker's own words and confirming understanding; 2.3 Does not interrupt or start talking while others are talking; 2.4 Is open and shows true interest in new ideas; 2.5 Confirms message/information is understood or, when needed, asks for clarification, examples and/or details; 2.6 Makes clear when, where and how ideas, emotions and opinions are welcome; 2.7 Makes clear how ideas and opinions will be treated.

I3 - Choose communication styles and channels to meet the needs of the audience, situation and management level: 3.1 Selects appropriate communication channels and style depending on the target audience; 3.2 Communicates via selected channels according to the selected style; 3.3 Monitors and controls communication; 3.4 Changes the communication channels and style depending on the situation.

I4 - Communicate effectively with virtual teams: 4.1 Uses modern communication technology, (e.g. webinars, tele-conferences, chat, cloud computing); 4.2 Defines and maintains clear communication processes and procedures; 4.3 Promotes cohesion and team building.

I5 - Employ humour and sense of perspective when appropriate: 5.1 Changes communication perspectives; 5.2 Decreases tension by use of humour.

The PBL methodology in engineering education: discipline description and analysis at the Institut National des Sciences Appliquées Lyon in France

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Abstract

The PBL method seeks to modify the conventional model of information transmission and reception through creative problem solving, encouraging students to be active in the construction of knowledge. This paper describes the PBL method adoption in the Atelier discipline at the Institute National des Sciences Appliquees - INSA, Lyon city in France, allowing to know its stages of application and the potential of diffusion. The methodology includes a detailed description and analysis of the experience through the PBL method was carried out. The results allowed to verify that the adoption of the method in the discipline collaborated for the technical knowledge acquisition on the subject addressed and also in the skills development often requested by civil engineering professionals, proving effective in its main objectives.

Keywords: Problem-Based Learning; Civil engineering; Institute National des Sciences Appliquées.

1 Introduction

The shortcomings in the current model of professional training stem from various issues of undergraduate program, such as the disinterest and apathy from students in the classroom, lack of initiative, in addition to the low supply of practical and dynamic content. Palma (2020) states that the conventional educational model, based on the transmission and reception of fixed and finished knowledge, where the learning process takes place passively, is incompatible and insufficient to prepare individuals for professional performance in today's world.

The conventional teaching model, predominant in universities, according to Mendonça *et al.* (2015), is characterized by the transmission of knowledge, the emphasis on memorization, and damage to critical reflection, essentially based on lectures, where only the teacher knows and is the main protagonist while the students faithfully repeat the memorized contents in tests. Moutta and Rodrigues (2020) emphasizes that nowadays it is extremely important to present the teacher as a mediator in the learning process and not as a mere communicator of knowledge.

The current engineering training model needs updates so that new professionals satisfactorily meet the transformations and challenges of today's society. The teaching-learning methods employed must favor the attributes stipulated in their guidelines or recommended by professional associations, since the information transmission-reception model does not encourage the development of creativity, entrepreneurship, and the ability to learn independently. (STOFFEL; PEEMOLINI-BARRETO; SILVA, 2020).

Several teaching-learning methods can be used to promote this achievement. In a sense, all forms of active and/or collaborative learning, process- and/or student-centered, and constructivist teaching methods serve this purpose (VIANA; SILVA, 2022). According to Silvestre *et al.* (2010), active learning methods provide the design of a knowledge network, progressive and continuous, for the training of competent, proactive, and ethical professionals in professional actions.

Hansen; Lehn; Eckhardt (2021) state that among the most important active strategies and methodologies currently used in higher education are problematization; case study; seminars; Problem-Based Learning; Project-Based Learning; learning between pairs or teams (Team-Based Learning); flipped classroom; and concept maps. Among the methods stands out Problem-Based Learning (PBL), or PBL (Problem-Based Learning), as it is commonly known.

Unlike conventional teaching methods whose assessment of competence is strongly based on content, in PBL the teaching-learning strategy is stimulated at several different levels with a great incentive to innovation, the use of new technologies, practical and collaborative activities, and also to creative problem solving, encouraging students to be active in the construction of knowledge. (STOFFEL; PEEMOLINI-BARRETO; SILVA, 2020). As it is an active teaching method, PBL has been evaluated as an alternative for improving engineering education and for the development of skills that go beyond the technical knowledge required by the market.

2 Theoretical Reference

2.1 Scope Problem Based Learning (PBL)

Problem-Based Learning (PBL) as it is known internationally, is a teaching-learning methodology in which the presentation of a problem situation is used to motivate students to study. For Gomes and Rego (2011), problem situations are an important part of a curriculum because they provide the curiosity of the search and integrate the areas of knowledge, allowing interdisciplinarity and an instigating and cooperative work process.

According to Silva and Gontijo (2015), in PBL, the oral exposition of the subject, in the way it occurs in traditional teaching, is significantly reduced and students work in self-regulated groups and the teacher assumes the role of tutor or learning advisor. The PBL sections always begin with the presentation of a problem situation involving concepts not previously worked on, which are submitted to analysis by the students, who try to define and solve them using the knowledge they have.

From this initial discussion, students: raise hypotheses and defend them, based on the data presented in the problem; prioritize hypotheses, and determine the concepts to be explored; determine the responsibilities of each group member, deadlines, research sources, etc.; reach a satisfactory solution, they present it and defend it before the class and the tutor; and finally they evaluate the process, themselves and the group (ESCRIVÃO FILHO; RIBEIRO, 2008).

In addition, in the view of many students, PBL has some benefits for learning that are often not encouraged in traditional teaching methodologies, they are the encouragement of autonomous study and research; development of teamwork skills; promotion of communicative skills; greater student participation in the classroom; greater teacher-student and student-student interaction; greater involvement and commitment to the discipline; promoting a diversity of views on the program's themes; greater contact with situations of professional practice and approximation of theory to practice and greater empowerment of students over the discipline (ESCRIVÃO FILHO; RIBEIRO, 2009).

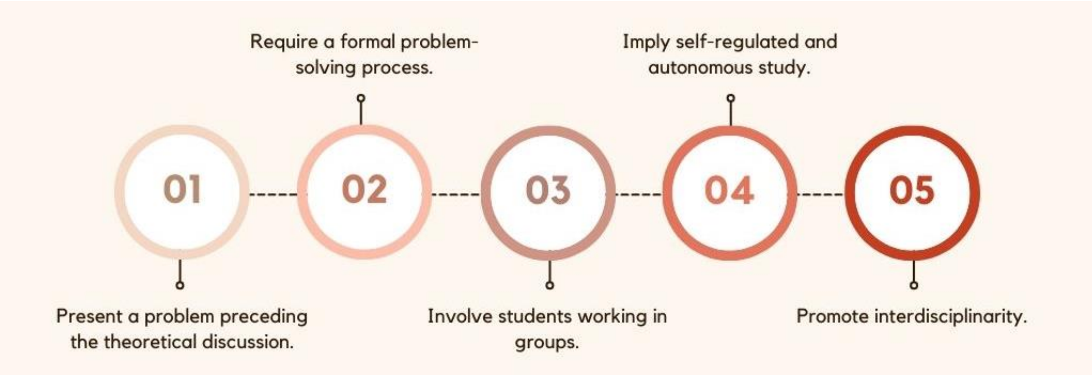

Figure 1. Essential elements of PBL.

Teaching using the PBL methodology, according to Ribeiro (2008) has five essential elements, which can be seen in Figure 1. Although there are different ways of implementing PBL, they all have in common a set of processes that must be followed (BERBEL, 1999; RIBEIRO and MIZUKAMI, 2004; WILLIAMS, IGLESIAS and BARAK, 2008; SILVA, 2014), as described in Figure 2.

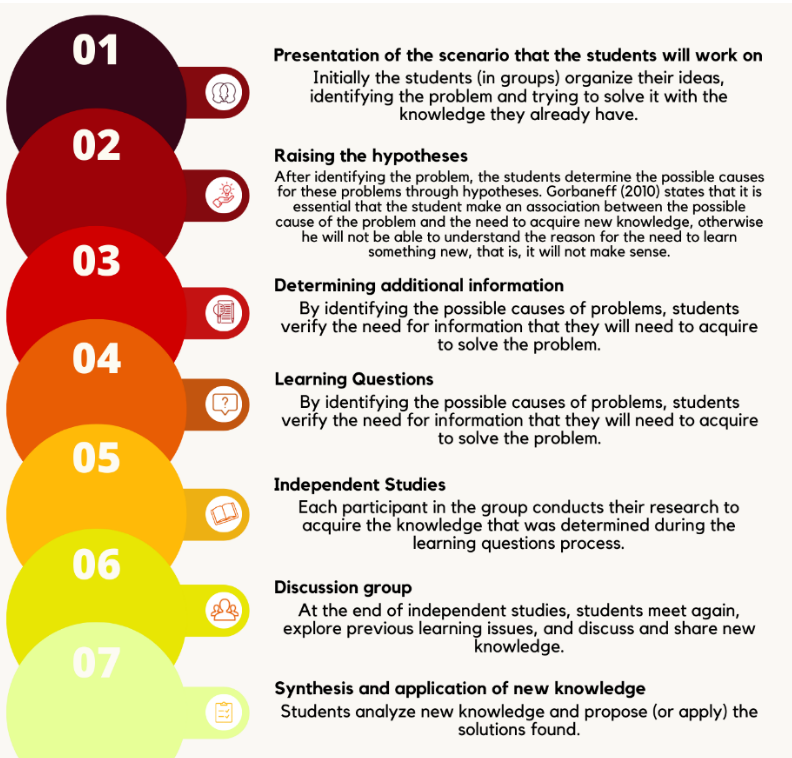

Figure 2. PBL stages.

2.2 PBL experience history in the universities

According to Araújo et al. (2014), in Brazil and abroad, there are reports of works that studied the implementation of PBL in disciplines in programs such as Engineering, Administration, Medicine, Architecture, Accounting Sciences, Pedagogy, among others. In all studies, PBL is advocated for, although there are observations about the method not being the solution to all teaching and learning problems at an undergraduate level.

Existing records suggest the first discussions of this method around 1930 at the Harvard Business School in the United States and at Maastricht University in the Netherlands, as well as later educational experiences in Africa, Asia and Latin America (ASSIS, 2012). However, McMaster University, Canada, was recognized as responsible for the pioneering introduction of PBL into the school curriculum of the Faculty of Medical Sciences in 1969 (GOMES E REGO, 2011).

From then on, several schools began to adopt this teaching method, including Harvard University, which began experimenting with PBL in 1984 in its Medicine Program; Maastricht University, in the Netherlands, and Venturelli University, which has been developing the methodology since 2000; and the University of Colima, Mexico, where it has been used since 1999 (KODJAOGLANIAN et al., 2003; CEZAR *et. al*., 2010; LOPES *et. al*., 2011).

In Brazil, the use of PBL in curricular structuring is also more common in higher education institutions, including the School of Arts, Sciences, and Humanities at the University of São Paulo (USP) and the Medicine Discipline at the Federal University of São Paulo. Carlos (UFSCAR) (LOPES *et. al.,* 2011), the Faculty of Medicine of Marília (FAMENA) in the Nursing Discipline (MARIN *et. al.,* 2004), the Faculty of Medicine of the State University of Londrina (UEL) and the Serra dos Órgãos University Center (UNIFESO) (CEZAR *et al.,* 2010).

2.3 The PBL method applied to civil engineering

Many skills are required from the engineering profession. According to Oliveira *et al.* (2013), these skills should develop during the undergraduate discipline. Among them, an engineer is required to have the creativity to deal with various problems; they must have the set of methods to deal with such issues.

Peixoto and Braga's (2007) research investigates the necessary competencies of the civil engineer's professional practice, namely: the ability to adapt to changes, ability to work in a team, ethical behavior, creativity, discipline, initiative, and leadership.

While researcher Ribeiro (2008) points out the use of PBL in the teaching-learning process in civil engineering undergraduate programs for the development of problem-solving skills, independent study, communication, self-regulated work, interpersonal relationships, respect for colleagues' opinions, and collaboration.

2.4 Importance of the PBL method for training engineers

The role of the engineer, according to Silva (2014), has reached areas that in past decades were considered inaccessible, such as finance, marketing, and consumer services, among others. Such expansion, potentiated by the fact that the functions performed by the engineer are, normally, of leadership, end up demanding multiple skills. The engineer needs to be in line with current market demands, and for that, they must develop skills such as the ability to learn and adaptability.

To meet the requirements of engineering and promote essential skills to professionals, changes are necessary, including in the process of training the engineer. The engineering teaching model must not be limited to promoting conceptual-theoretical knowledge and favors reflective-conclusive thinking in its students.

As a result of these changes in engineering education, Powell (2000) attributes to PBL a greater initiative on the part of students, who seek to acquire the necessary knowledge to work on the project, in addition to learning to respect the established deadlines. Thus, according to Schnaid *et al.* (2003), the PBL method can be applied to some disciplines of engineering programs, seeking to develop skills and abilities necessary for the success of the engineering profession.

5 Research methodology

For the development of this research, the methodology adopted included the following steps:

Stage I – literature review: descriptive research, gathering knowledge available in books, dissertations, theses, conference proceedings, and journals related to the Problem-Based Learning method - PBL. This step made it possible to build a theoretical framework and establish the characteristics to be considered for the analysis of the case study.

Stage II – description of the case studied: details of how the Atelier discipline taught at the National Institute of Sciences Appliquées - INSA was conducted with the adoption of the PBL method, attended by one of the authors, which was used to exemplify how the method is adopted to develop knowledge at INSA. The aspects described refer to the objectives of the discipline, the methodology adopted during its development, the contents presented during the classes, the final work developed in groups and the form of evaluation; and

Stage III – analysis of results: analysis of the Problem-Based Learning method within the Atelier discipline, comparing the characteristics identified in the case study with those found in the literature review stage.

6 Results obtained - case study

The Institute National des Sciences Appliquées - INSA is a French research and higher education institute that has five campuses, located in the cities of Lyon, Rouen, Toulouse, Strasbourg, and Rennes. INSA is composed of 7 National Institutes of Science and Technology (INSA) in France and one in Morocco. 6 other schools of engineering are associated members. As the largest French public community in engineering, the INSA Group is fully engaged towards the future, locally and globally speaking (INSA, 2023).

INSA is the largest organization for training engineers in France, being responsible for the training of 12% of engineers in that country and recognized as one of the best engineering schools in France (UNESP, 2016).

INSA aims to train engineers, participate in studies, research and tests, move the regions and facilitate social ascension. For this, the training of professionals is divided into two stages: in the first cycle, lasting two years, students receive basic scientific training, including group laboratory and science classes, and prepare to follow one of the 12 departments. The second cycle lasts three years and trains professionals from different programs, including Civil Engineering and Urbanism (Génie Civil et Urbanisme - GCU). In this program, graduation is carried out over five years with subjects focused on civil construction and urbanism (INSA, 2023).

6.1 Discipline description

The Atelier discipline is taught during the third and fourth year of the program, within the Urbanism module of the Civil Engineering and Urbanism program.

The discipline's main objective was to teach students the dynamics of problem-situation resolution from a methodology, motivated by a general theme, in relation to the act of conceiving, building or managing objects of Civil Engineering and Urbanism. More specifically, the discipline intended to teach how to: identify and formulate a relevant question in relation to the general theme, formulate one or more methods to answer the question, implement the proposed methods in specific cases found by the working group, and perform a critical analysis of the results and the method adopted. For that, the discipline was developed by 4 groups composed of 4 to 5 students, who, during 12 meetings of 4 hours each, aimed to develop the proposed work according to the class schedule presented in Table 1.

Table 1. Discipline lesson plan.

INTERVENTIONS	MEETINGS											
	1º	2º	3º	4º	5º	6º	7º	8º	9º	10º	11º	12º
Introductory class for the presentation of the discipline												
Present the annual problem of the discipline												
Self-guided group work												
Preparation of problem restitution + Definition of methodological elements + Self-guided group work												
Intermediate restitution of the proposed problematic: presentation and argumentation												
Self-guided group work												
Return of the methodology elements + Data analysis + Self-guided group work												
Self-guided group work												
Intermediate work restitution: presentation of procedures and their implementation + Bibliographic review												
Self-guided group work												
Oral presentation of works for evaluation												
Report of the results of presentations and works												

The discipline has three stages. The first one identifies the proposed problem, according to the annual theme presented by the professors as well as the formulation of the question to which the group proposes to answer. For this, hypotheses about the problem are developed and answers are sought through a literature review on the subject addressed, also allowing to justify the approaches adopted to answer the proposed question.

The second stage of the discipline is intended for the study and definition of the methodology to answer the question. The method should be based on tools for collecting and analyzing data from interviews, questionnaires, and observations, among others. In the third stage, data collection and analysis are carried out to respond to the problem initially proposed.

As a result, there is a presentation of the work of each group, followed by a discussion coordinated and intermediated by the professors with possible external participants. In addition to the presentation, a summary of the study developed is prepared, in paper format, for evaluation by the teachers. The final grade of the students is based on the oral presentation and the written work.

6.2 PBL stages in the discipline

The discipline, during the 2012-2013 term, had as its main theme "Cities and Energy", initially discussing the energy consumption sectors, such as the housing, industrial and commercial sector, public lighting, transport, and the adoption of new technologies, aiming to reduce the energy consumption of the city.

Within the proposed central theme, several problem situations were exposed, such as the increase in energy consumption in cities due to the use of technological products; greater energy expenditure due to urban mobility; the reduction of energy consumption, influencing the comfort and safety of the population in public areas; and investments in existing buildings, aiming at improving energy performance.

Among the four stages, in the first activity, an oral presentation was carried out on the chosen problem situation, exposing and discussing arguments, in addition to explaining the approaches chosen by the group.

Then the evaluating professors made their statements about the presentation and problem-situation chosen, suggesting points to be improved and proposing questions to be answered.

The second activity consisted of another oral presentation, continuing the study, and exposing the tools adopted for collecting and analyzing data obtained through interviews, questionnaires, and observations, among others. This activity also considered the evaluation from the professors to verify if the methodology adopted by the group was adequate to respond to the chosen problem situation.

The third stage had another oral presentation in which each group presented the analysis carried out and results obtained through the adopted methodology proposed during the intermediation made by the teachers during the exposed activities. The evaluation of this activity, by the teachers, aimed to verify if the groups were able to answer the problem initially proposed, respecting the formulated hypotheses and the chosen methodology.

As for the last activity, a summary of the work was presented, in the form of a paper, composed of the following items: abstract in French and English, presentation of the chosen problem situation, state of the art (bibliographic review), methodology, analysis and results, conclusions, bibliography, and certificate of non-plagiarism. Through this study, it can be seen that the Atelier discipline, through the adoption of elements of the PBL method during its different stages, can help in the development of students' skills, according to the considerations in Table 2.

Table 2. Skills developed according to elements adopted in the discipline.

STAGES	FORM OF ADOPTION	SKILLS DEVELOPED
Present a problem preceding the theoretical discussion	Problem presentation class; Review of concepts	Critical reflection on the subject; Development of students' opinions.
Demand a formal process for problem solving	Research and choice of methodology to be adopted	Capacity to adapt to changes; Problems solution; Decision making
Involve students working in groups	Division of groups with different problems to work on	Promotion of communicative skills; Teamwork; Leadership; Respect to different opinions
Involve self-regulated and autonomous study	Classes for work development with or without tutor	Self-guided study; Discipline; Focus
Favor interdisciplinarity	Problem-situation involving several disciplines	Multidisciplinary reasoning

As for the processes developed for the adoption of the PBL method, the discipline covered them according to what is presented in Figure 3.

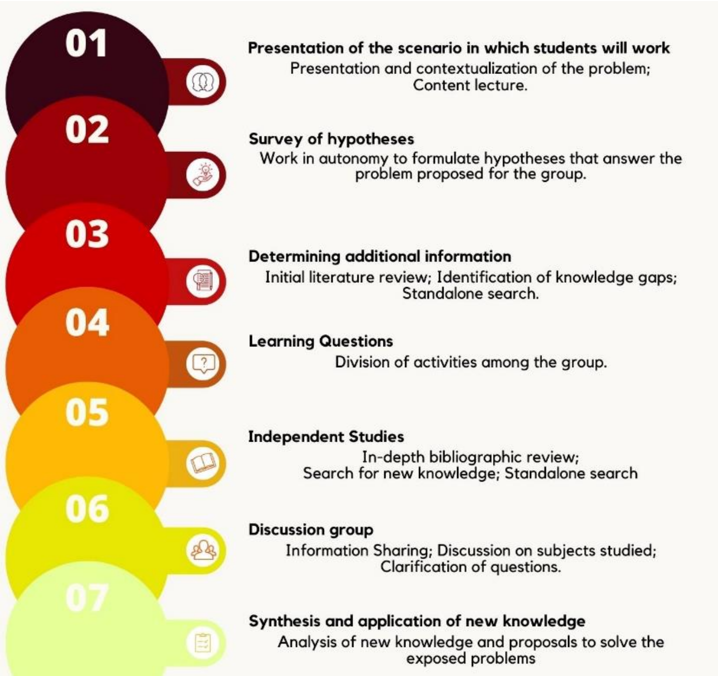

Figure 3. Skills developed according to elements adopted in the discipline.

In addition to adopting elements and processes of the PBL method observed in the discipline, the discussions promoted and mediated by the guiding professors allowed to add knowledge and deepen the issues of the problem situation initially proposed through the collaboration of students and teachers involved in the process. Such contributions have not only pointed to engineering but also social, urban, and economic aspects, providing the students a comprehensive view of various issues.

The division of work into four parts, including three oral presentations, provided students with the development and improvement of communicative and expository skills such as problem-solving, communication, debates, and critical thinking about the themes of both their group and others, in addition to the teamwork, leadership, and respect for differing opinions. It is noteworthy that, in this work, information sharing among students of the same discipline was promoted through the mediation of professors-advisors. Therefore, they were able to help by questioning and exposing opinions about the problem situation proposed by other groups.

7 Conclusions

It was observed that the adoption of the PBL method in a discipline of the civil engineering discipline contributed not only to the development of technical knowledge within the classroom but also to the development of skills for future engineering professionals.

It was also found that exposure to problems related to specific contents of civil engineering motivates students to learn and makes them active actors in the teaching-learning process. Concerning teamwork, students developed problem-solving skills, decision-making, and respect for the opinion of colleagues, in addition to developing oral and written scientific communication. However, the adoption of the PBL method in a semester at the French university took place partially since it was intended for isolated subjects within the conventional curriculum.

Finally, it should be noted that the adoption of the PBL method does not guarantee the solution of all problems related to engineering education, nor does it offer a guarantee to successful students in the job market. It stimulates, however, and develops students and professionals who are active and engaged in problem-solving.

It is worth noting that each student has a different learning style, and it is up to the mediator teacher to understand and adapt the method studied in the most appropriate way within the context of the class so that all parts involved act as active agents in the learning process.

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8 References

Araújo W. J.; Lopes R. P; Oliveira Filho D.; Barros P. M. M. & Oliveira R. A. Aprendizagem por problemas no ensino de Engenharia. Revista Docência do Ensino Superior, Belo Horizonte, v. 6, n. 1, p. 57-90, abr. 2016.

Assis, M. P. PBL. Grupos colaborativos e assembleia escolar: integração de ensino, prática docente e pesquisa no âmbito da formação de educadores. In: International Conference PBL, Cali, Colômbia, 2012.

Berbel, N. N. "Problematization" and problem-based learning: different words or different ways? Revista Interface, v.2, n.2, 1999.

Cezar, P. H. N. et al. Transição paradigmática na educação médica: um olhar construtivista dirigido à aprendizagem baseada em problemas. Revista brasileira de educação médica, Rio de Janeiro, v. 34, n. 2, p. 298-303, 2010. Disponível em: <http://www.scielo.br >. Acesso em: 03 set. 2017.

Escrivão Filho, E. & Ribeiro, L. R. C. Aprendendo com PBL: aprendizagem baseada em problemas: relato de uma experiência em cursos de engenharia da EESC-USP. Revista Minerva, São Carlos, v. 6. n. 1, p. 23-30, jan./abr. 2009. Disponível em: <http://www.fipai.org.br >. Acesso em: 02 set. 2017.

______. Inovando no ensino de administração: uma experiência com a aprendizagem baseada em problemas (PBL). Cad. EBAPE.BR, Rio de Janeiro, v. 6, n. esp., p. 1-9, ago. 2008. Disponível em: <http://www.scielo.br >. Acesso em: 03 set. 2017.

Gomes, A. P. & Rego, S. Transformação da educação médica: é possível formar um novo médico a partir de mudanças no método de ensino-aprendizagem? Rev. bras. educ. med., Rio de Janeiro, v. 35, n. 4, p. 557-566, dez. 2011. Disponível em: <http://www.scielo.br>. Acesso em: 02 set. 2017.

Hansen, B.; Lehn, D. N. & Eckhardt, R. R. 2021. "Metodologias Ativas No Ensino De Engenharia: Ênfase Na Utilização De Mapas Conceituais Na Aprendizagem Significativa." Revista de Ensino de Engenharia 40(1): 15–27.

Kodjaoglanian, V. L. et al. Inovando métodos de ensino-aprendizagem na formação do psicólogo. Psicologia, Ciência e Profissão, Brasília, v. 23, n. 1, p. 2-11, 2003. Disponível em: <http://www.scielo.br >. Acesso em: 03 set. 2017.

INSA - Institute National des Sciences Appliquées. 2023. Disponível em: <https://www.insa-lyon.fr/en/insa-lyon>. Acesso em: 25 mar. 2023.

Lopes, R. M. et. al. Aprendizagem baseada em problemas: uma experiência no ensino de química toxicológica. Química Nova, São Paulo, v. 34, n. 7, p. 1275-1280, 2011. Disponível em: <http://www.scielo.br. Acesso em: 03 set. 2017.

Marin, M. J. S. et al. Fazendo e aprendendo: uma experiência de ensino/aprendizagem. Revista brasileira de enfermagem, Brasília, v. 57, n. 1, p. 74-78, fev. 2004. Disponível em: <http://www.scielo.br. Acesso em: 01 set. 2017.

Mendonça, E. T.; Cotta, R. M. M; Lelisc, V. P. & Carvalho Junior, P. M. Paradigmas e tendências do ensino universitário: a metodologia da pesquisa-ação como estratégia de formação docente. Revista Interface, Botucatu, vol.19 no.53 abr./jun. 2015.

Moutta, R. O. & Rodrigues, G. C. Metodologias Ativas No Ensino Superior – Um Estudo De Caso De Desenvolvimento De Projeto. Rev. Ensino Eng.39, 137–146 (2020).

Oliveira, E. C.; Barcelos, M.; Arboleda, D. M. M.; Mendes, F. F.; Araujo, T. M.; Chaim, R. M.; Oliveira, A. B. & Hung, E. M. Projeto Integrador de Engenharia: Experiência de uma disciplina em busca por uma didática em ambiente desafiador. In: XII Congresso Brasileiro de Educação em Engenharia – COBENGE. Gramado, 2013.

Palma, E. S. Aplicação De Metodologia Ativa De Aprendizado Em Combinação Com a Ferramenta Moodle No Ensino De Mecânica Dos Materiais Do Curso De Engenharia Aeroespacial Da Ufmg. Revista Ensino de Engenharia, 26–38 (2020).

Peixoto, M. C. L. P. & Braga, M. M. Graduação e exercício profissional: formação e trabalho de engenheiros graduados na UFMG. Belo Horizonte: Editora da UFMG, 2007.

Powell, P. From classical to project-led education. In: POUZADA, A. S. (ed.). Project based learning: project-led education and group learning. Guimarães: Editora da Universidade do Minho, p. 11-40. 2000.

Ribeiro, L. R. C. Aprendizagem baseada em problemas (PBL): uma experiência no ensino superior. São Carlos: UduFSCAR, 2008.

Ribeiro, L. R. C. & Mizukami, M. G. N. Uma implementação da aprendizagem baseada em problemas (PBL) na pós-graduação em engenharia sob a ótica dos alunos. Semina: Ciências Sociais e Humanas, v. 25, p. 89-102, 2004.

Schnaid, F.; Timm M. & Zaro, M. A. Considerações sobre uso de modelo construtivista no ensino de Engenharia. Anais... In: 25a RBA Saberes e práticas antropológicas desafios para o século XXI, v. 1, p. 1-21, 2003.

Silva, J. K. F. & Gontijo, F. B.. Aplicação do Método Aprendizagem Baseada em Problemas (ABP) ao Curso de Engenharia Civil do UNIPAM. Anais... In: VIII Encontro de Pesquisa em Educação e III Congresso Internacional Trabalho Docente e Processos Educativos, 2015, Uberaba: Universidade de Uberaba - UNIUBE, 2015. v. 1.

Silva, M. C. D. V. Análise da Aprendizagem Baseada em Problemas no Ensino de Engenharia de Produção. 2014. Dissertação (Mestrado) - Universidade Federal De Itajubá, Itajubá, 2014.

Silvestre, V. et al. PBL e Agenda 21- Problemas socioambientais na graduação de gestão de políticas públicas para sustentabilidade. In: CONGRESSO INTERNACIONAL DE PBL, R0502-2, 2010, São Paulo. Congresso Internacional - PBL 2010, Universidade de São Paulo - Escola de Artes Ciências e Humanidades, 2010.

Stoffel, F.; Piemolini-Barreto, L. T. & Silva, P. J. 2020. "Metodologias Participativas E Aprendizagem Baseada Em Problemas No Curso De Engenharia De Alimentos." Revista de Ensino de Engenharia 39(1): 337–46.

Viana, L. L. . & Silva, N. C. da. Ensino de genética na educação básica baseado nas sessões tutoriais do método PBL. Revista de Ensino de Biologia da SBEnBio, v. 15, n. 1, p. 239–259, 2022. DOI: 10.46667/renbio.v15i1.684. Disponível em: https://renbio.org.br/index.php/sbenbio/article/view/684. Acesso em: 25 mar. 2023.

PBL in a University-Business cooperation in Engineering and Operations Management Master: challenges and opportunities

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Abstract

The active learning methodology Project Based Learning (PBL) has as main objectives: to involve and motivate students to learn actively while solving an open-ended problem, promoting their creativity, and stimulating their critical thinking Students are organized in teams and are challenged to solve real-world problems during a semester integrating contents from all or some of the courses, involving or not an external entity (e.g., a company), through large interdisciplinary project development. This paper discuss a pedagogical experience undertaken for the first time in the Engineering and Operations Management (EOM) Master that applied PBL in partnership with companies. The PBL involved five companies, six courses, six teachers, and 36 students organized in five teams. From the EOM courses of first semester, four integrated the project, two compulsory and two electives courses. Each student select two courses. This means that a team could include members attending different courses. The coordination responsibility was of the Integrated Project course. For each team, four milestones were planned, each with one or more deliverables, to accomplish the project objectives. This paper describes the PBL planning and organization, results, challenges, and improvement opportunities. Students' feedback was gathered through an online questionnaire composed of a total of 61 questions. From these, 58 are based on a five-point Likert scale and the last three are open-ended questions. A quantitative analysis was performed based on 23 (64%) respondents. At the end of the semester, additional students' feedback was also collected through a focus group. Moreover, a qualitative analysis was done based on the first-person narratives of four companies' supervisors. The main findings highlighted students' overall satisfaction, despite the many challenges faced. Nevertheless, less positive aspects were also identified and seen as improvement opportunities for the next edition.

Keywords: Active Learning; Engineering Education; Project-Based Learning, University-Business Cooperation.

1 Introduction

Currently, there are a lot of active learning methodologies, where some are referred to as X-based learning, X being the designation of, namely, problem/project, team, game, and challenge, among others (Pecore, 2015). Probably, Project-Based Learning (PBL) is one of the most popular, with roots in the seminal works of Dewey (1916) and his pupil, Kilpatrick (1918). Both envisioned the need for a purposeful activity in the education process. This act, i.e., developing a project, allows learning to take place.

According to Knoll (1997), learning by projects has a long history that started in the 16th century at architectural schools in Europe. Today, this is not limited to architecture and many teachers and educators from other areas are using it to engage and motivate students to learn. Some examples in different domains can be found in the literature (Alves et al., 2019; Alves & van Hattum-Janssen, 2022; Frank et al., 2003; Helle et al., 2006; Kekkonen & Isoherranen, 2021; Kokotsaki et al., 2016; Rui M. Lima et al., 2017; Pereira & Barreto, 2016; Robinson & Beneroso, 2021).

Pecore (2015) considered that implementing a project or activity is not enough to be considered PBL unless five definitive features are met. Based on Barron and Darling-Hammond (2008) and Thomas (2000), he defined the essential features of PBL: 1) a central project; 2) a constructivist focus on important knowledge and skills; 3) a driving activity in the form of a complex question, problem, or challenge; 4) a learner-driven investigation guided by the teacher; and 5) a real-world project that is authentic to the learner.

Being a student-centred approach, PBL benefits for students include the development of interdisciplinary technical competencies but also transversal competencies, such as critical thinking, teamwork, autonomy, awareness of real problems, problem-solving, communication, time and conflict management, among others (Alves et al., 2020; Edström & Kolmos, 2014; Fernandes et al., 2014; Graaff & Kolmos, 2007; Jollands et al., 2012; Lima et al., 2007; Mills & Treagust, 2003; Powell & Weenk, 2003). Some opinions of students and alumni that were involved in PBL are aligned with these competencies, adding to the list the learning environment that resembles their future professional daily life (Araujo & Manninen, 2021; Marinho et al., 2022).

Furthermore, when a company is introduced as one "course" in the project, bringing the problem to be solved by the students, the PBL pedagogical experience becomes richer but, at the same time, more complex. Some PBL implementations in the context of University-Business cooperation (UBC) have been happening to achieve good results for the students and the companies (Alves & Abreu, 2021; Dinis-Carvalho et al., 2017; Lima et al., 2015; Lima et al., 2017; Lima et al., 2014; Lima et al., 2017).

According to Davey et al. (2018), based on the results of a survey administered in 2016, the engagement of academics and businesses was still limited, reducing the labour market relevance of the study programmes, the employability of graduates and the impact of research. Hence, it is important to increase this engagement, as is highly positive for all parties involved. This report also shows that businesses were starting to see Higher Education Institutions (HEI) as a source of future-oriented innovation, talent development, and entrepreneurship and as a lead players in regional development that can build a competitive advantage. For the students, this provides a huge opportunity to learn in a real context and solve real problems, closing the gap between the theoretical with practical contents and better preparing them for their professional future (Alves et al., 2017; Davey et al., 2018; Lima et al., 2018).

The "Integrated Project" course emerged from this need and from the authors experience in related projects. It was introduced in the first semester of 2022_23 in the second year of Engineering and Operations Management Master of the University of Minho. This course was planned for students to work in teams in a PBL context collaborating with companies. Companies must be available to present a problem and receive and support the teams throughout the project. This paper reports how this PBL edition was planned, organized and managed, as well as the challenges and opportunities that emerged. Thirty-six students organized in five teams of seven-eight members were involved, supported by the IP coordinator, teachers from the courses and companies' supervisors. From the five courses of the first semester, only four integrated the project, two compulsory and two electives courses. Each student was enrolled in two elective courses but four elective courses were in function. This means that, in a team, members could have different elective courses what was a challenge of this project and different from other presented in the literature.

This paper is structured into five main sections. After this first section that contextualizes and presents the objectives, the second section presents the research methodology used. The third section presents the study context. The fourth section presents the results and discusses feedback provided by students, companies and teachers involved. Finally, the concluding remarks are given in section five.

2 Research methodology

The research methodology used to collect experience results comprise a questionnaire and a focus group developed during a workshop promoted by the teachers' team coordinator at the end of the semester. In addition, the companies' supervisors provided written feedback about the projects developed by the teams in the companies.

The questionnaire was adapted from a questionnaire previously developed to evaluate PBL of the first year, first semester of the Industrial and Engineering Management degree (Alves et al., 2020). For the IP course, the questionnaire was structured into seven main sections: I) Project theme (challenge) (7 items); II) Learning and skills development (10 items); III) Teamwork (15 items); IV) Teacher's role (7 items); V) Assessment model (10 items), VI) PBL as teaching/learning methodology (9 items) and VII) Open-ended questions (3 items). A total of 58 items were evaluated based on a 5-point agreement Likert scale (1- strongly disagree to 5- strongly agree), the last three open-ended questions. Table 1 presents the dimensions and items of the questionnaire.

The focus group was integrated into the workshop organized at the end of the semester to discuss and collect more personal feedback from the students. This workshop involves the presentation by the coordinator of the grades obtained by the students and discussing with them what satisfied more and less and improvements suggestions. The focus group has four main discussion themes: 1) peer assessment; 2) project and support from the company; 3) integration of courses and 4) Teachers' support and feedback.

Table 1. Questionnaire dimensions and items.

Dimension	ID	Items
I. Project theme	Q1	The challenge of the project was adequate to understand my future professional activity.
	Q2	I think the challenge of the project was interesting and motivating.
	Q3	The fact that the project is open (with several solutions) was a stimulating challenge.
	Q4	For the learning of the courses this semester, I consider that the proposed project was adequate.
	Q5	The articulation between the courses of the semester was well achieved with the project.
	Q6	I am proud of the project my group has built.
	Q7	I consider that the chosen company was adequate to develop the project.
II. Learning and skills development	Q8	The project allowed me to better understand the relevance of the contents of the courses.
	Q9	Through the project, it was possible to be aware of the content's application in real situations.
	Q10	I feel that my participation in the PBL helped to develop my autonomy.
	Q11	During the semester, I improved my communication skills (oral and written).
	Q12	The development of this project was important and allowed me to develop my critical spirit.
	Q13	The solutions construction (e.g., dashboards) stimulated my capacity for initiative and creativity.
	Q14	The creation of a blog was useful for the organization and dissemination of the team's project.
	Q15	The blog was a tool that helped to select, organize and register the contents related to the project.
	Q16	The blog was a tool that helped keep an up-to-date record of the project's progress.
	Q17	The blog was a tool that encouraged writing (in English) about the contents related to the project and some curiosities.
III. Teamwork	Q18	Teamwork has helped to increase my motivation for learning.
	Q19	I prefer to work in groups than individually.
	Q20	During the semester, I played an active role in the group.
	Q21	The existence of roles in the group (president, secretary, time manager) was fundamental to understand better those roles.
	Q22	During the project, my group held formal meetings and produced meeting minutes.
	Q23	I consider that the interpersonal skills that I have developed are important for my future professional activity.
	Q24	I shared the results of my tasks and knowledge with the rest of the group.
	Q25	I was able to solve the conflicts in the group and face them positively.
	Q26	I applied techniques to support teamwork that were useful to progress in the project.
	Q27	I feel that I performed well as a member of a team.
	Q28	When I disagreed with the rest of the team, I always ended up reaching an understanding.
	Q29	After each meeting and task completed, I always left confident and in a good mood.
	Q30	In each team meeting, I tried to understand the feelings of each member when they were angry, upset or sad.
	Q31	I was not able to fulfil the task that had been assigned to me, I asked the other teammates for help.
	Q32	When a colleague did the task correctly, I praise him/her.
IV. Teacher's role	Q33	Teachers were available to support students.
	Q34	Teachers provided the technical support needed to complete the project.
	Q35	The performance of the teachers corresponded to my expectations.

	Q36	The professors of the courses could be team tutors (one professor per team).
	Q37	The contents taught by the professors were sufficient to complete the project.
	Q38	I found it stimulating to have to look for other sources of information to complement those of the professors.
	Q39	I think I realized how the courses were integrated to define solutions.
V. Assessment model	Q40	I have read and understood the assessment criteria in the Student Guide.
	Q41	The number and type of milestones during the project are adequate.
	Q42	Teacher feedback on reports and presentations was clear.
	Q43	Peer assessment is an appropriate tool for evaluating teamwork.
	Q44	The results of the peer assessment reflect the commitment of each element.
	Q45	Evaluating the presentations of other teams should be mandatory.
	Q46	I believe that the company representative should also quantitatively evaluate the solutions.
	Q47	The classification obtained in the project should be the same for all team members.
	Q48	I think the weight of deliverables (presentations, articles, blog) is adequate.
	Q49	In general, I am satisfied with the results obtained at the project.
VI. PBL as teaching/ learning methodology	Q50	PBL facilitated my academic learning and professional life.
	Q51	I believe that the PBL contributes to reduce academic abandonment and failure.
	Q52	The PBL has a positive impact on the relationship established with teachers and department.
	Q53	Overall, I think the PBL was well organized.
	Q54	The information available in the Student Guide was clear, useful and sufficient.
	Q55	The suggested tools for delivering documents and communicating with professors (e-mail, WeTransfer, Blackboard) were adequate.
	Q56	The project coordinator regularly reported on the activities of the PBL.
	Q57	PBL requires excessive effort when compared to any other course of the semester.
	Q58	I believe, however, that this effort is compensated with the skills acquired.
VII. Open-ended questions	Q59	The most positive aspects of participating in the PBL were....
	Q60	The less positive aspects of having participated in the PBL were....
	Q61	Within the scope of this project, I propose the following suggestions for improvement (e.g., type of deliverables, having fewer control points, having tutors, type of company, ...)

The questionnaire was answered by 64% of participants (23 of 36) in the project which was considered a good response rate. Teachers' feedback was based on open-ended questions: 1) What went well? 2) What went wrong? And 3) What can be improved?

3 Study context

This section describes succinctly the Engineering and Operations Management Master (EOM) and the Integrated Project course.

3.1 Engineering and Operations Management Master

This section presents the context of the Engineering and Operations Management Master (former Industrial Engineering Master). The Department of Production and Systems of the School of Engineering of the University of Minho offered Industrial Engineering Master's from more than two decades. It was a second-cycle master of 120 European Credit Transfer System (ECTS). The second year had only two courses of five ECTS: Seminars in Industrial Engineering (SEI) (Alves et al., 2022) and Methods of Research in the first semester. It included an annual Master's dissertation of 50 ECTS. The semester totalized 60 ECTS.

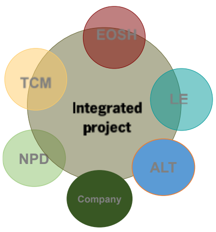
Many of the students that enrolled in this program were young professionals who worked in companies and their feedback was that more could be done this semester to enrich the master's. Attending to this feedback and the need to restructure the master's degree course, the first semester of the second year was changed to include three compulsory courses, two elective courses and the dissertation with 35 ECTS, which continue being annual, as represented in Table 2. The semester continues totalizing 60 ECTS for each student but it was allowed by the department the offering of four elective courses most chosen by the students. Thus, in this particular year of 2022_23 the courses in function were the ones represented in Table 2. It was decided not to include RMISE as this course is offered to other masters.

Table 2. Engineering and Operations Management Master courses of the second year, first semester (2022_23).

Type	Designation	Number of ECTS
Compulsory	Research Methods in Industrial and Systems Engineering (RMISE)	5
Compulsory	Ergonomics and Occupational Safety and Health (EOSH)	5
Compulsory	Integrated Project (IP)	5
Elective I.1	Advanced Lean Tools (ALT)	5
Elective I.2	New Product Development (NPD)	5
Elective II.1	Lean Enterprise (LE)	5
Elective II.2	Team and Communication Management (TCM)	5
Dissertation	*(To be developed in academic, industrial or institutional context)*	35 (annual)

3.2 Integrated project

The process and operation of the Integrated Project (IP) was described in a document called Interdisciplinary Learning Project Guide (Equipa de coordenação 2022_23, 2022) and delivered to the students in the first class of IP. This document presents the PBL process, its advantages and disadvantages, the stakeholders (students, coordination team, companies involved), project/challenged description, course' competencies to acquire in each, schedule base and tutorial support, milestones, assessment methodology and physical resources. Some of these elements are described in the following sections. Figure 1 presents the courses and the company in the IP and students' teams, electives chosen by each student and the companies involved.



Number	Elect.I	Elect.II	Team/ Comp.	Number	Elect.I	Elect.II	Team/ Comp.	Number	Elect.I	Elect.II	Team/ Comp.	Number	Elect.I	Elect.II	Team/ Comp.	Number	Elect.I	Elect.II	Team/ Comp.
Stud.1	NPD	TCM	Team1/ Comp.1	Stud.8	ALT	LE	Team2/ Comp.2	Stud.15	ALT	LE	Team3/ Comp.3	Stud.22	NPD	LE	Team4/ Comp.4	Stud.29	ALT	TCM	Team5/ Comp.5
Stud.2	NPD	LE		Stud.9	ALT	TCM		Stud.16	NPD	LE		Stud.23	NPD	LE		Stud.30	ALT	LE	
Stud.3	ALT	LE		Stud.10	NPD	LE		Stud.17	ALT	LE		Stud.24	ALT	TCM		Stud.31	ALT	LE	
Stud.4	ALT	TCM		Stud.11	NPD	TCM		Stud.18	ALT	LE		Stud.25	ALT	TCM		Stud.32	ALT	TCM	
Stud.5	ALT	LE		Stud.12	NPD	TCM		Stud.19	ALT	TCM		Stud.26	ALT	TCM		Stud.33	NPD	LE	
Stud.6	ALT	TCM		Stud.13	ALT	TCM		Stud.20	ALT	TCM		Stud.27	ALT	TCM		Stud.34	ALT	TCM	
Stud.7	NPD	TCM		Stud.14	ALT	LE		Stud.21	ALT	LE		Stud.28	ALT	TCM		Stud.35	NPD	TCM	
																Stud.36	ALT	LE	

Figure 1. Courses involved in the IP and students' teams, electives chosen by each student and the companies involved.

As the Figure shows, five teams were created that developed the project in different companies. Four teams had seven members and one team had eight members. Each student chose different electives, as can be seen in the Figure 1. This means that each team was composed of members enrolled in different courses, making each team different. Teachers' role was to support the teams with contents relevant to solve the problem, attending to the learning outcomes to be achieved.

The companies were contacted by the IP coordinator that described what was intended with this project. Later, an email was sent with a formal letter introducing the master, course, objectives, students' profile, and what was expected from companies. Six companies attended the call but due to the number of teams just five were selected. Each company representative made a presentation of the company and the challenge in a day scheduled for that. Three companies were international and two national.

Table 3 shows the four milestones defined for this project, as well as the deliverables and their respective assessment weights. The grades obtained from these deliverables were team grades.

Table 3. Milestones (Ms) and deliverables.

Ms.	Date	Deliverable	Weight (%)
1	2022.10.13 (Wk4)	Presentation through PM Canvas (10'/team+ 5' disc.).	10

2	2022.11.17 (Wk9)	Current status presentation & newsletter article (max. 5 pages)	15+10
3	2022.12.15 (Wk13)	Final presentation & discussion (15'/team+ 15' disc.).	25
4	2023.01.12 (Wk15)	Final article (max. 8 pages) + Blog (English language) + Prototypes (optional)	30+10

The individual grade of each student was only influenced by the peer assessment. Three peer assessments were filled up by each student and the coordinator compiled them and returned to the teams the result for them to discuss and validate.

4 Results and feedback

This section presents the results of the grades and the feedback from 1) students; 2) companies and 3) teachers.

4.1 Students

In general, the students had a good performance, as can be seen in Figure 2.

Figure 2. Individual grades obtained by the students.

The averages for each dimension obtained through the questionnaires are represented in Figure 3.

It is possible to see those students, in general, agree for most of the items, giving an average score of 4,4 to the Q6 (I am proud of the project my group has built.) and 4,0 to Q49 (In general, I am satisfied with the results obtained at the project.).

The most positive aspects were the contact and interaction with a company, the application of the knowledge acquired to real situations, learning to communicate more openly about existing problems and doubts, the learning to communicate problems and continuous teacher support. The less positive aspects were the number of deliverables, the unequal effort that members put into the project, transport costs to visit companies, the semester's high workload, the large team with conflicts, too many assessment moments and project duration, difficulty to conciliate schedules, communication difficulties with company, unfair peer assessment. The improvements suggestions were: fewer (or different) milestones and deliverables (e.g. eliminate blog), one support tutorial room or two but closer, substituting blog with an activity more dynamic such as organization of an event or inviting a speaker to talk about a relevant topic for the project, to have services companies to develop the projects, each team should have a tutor or a teacher that accompany the team to the company, put the PBL in the first year of the master, to select companies near the university, substitute final article by a report, compulsory presence of the students in the tutorial support classes, peer assessment after each milestone, teacher feedback too focused in the negative aspects, consider the company supervisor opinion and more attractive projects.

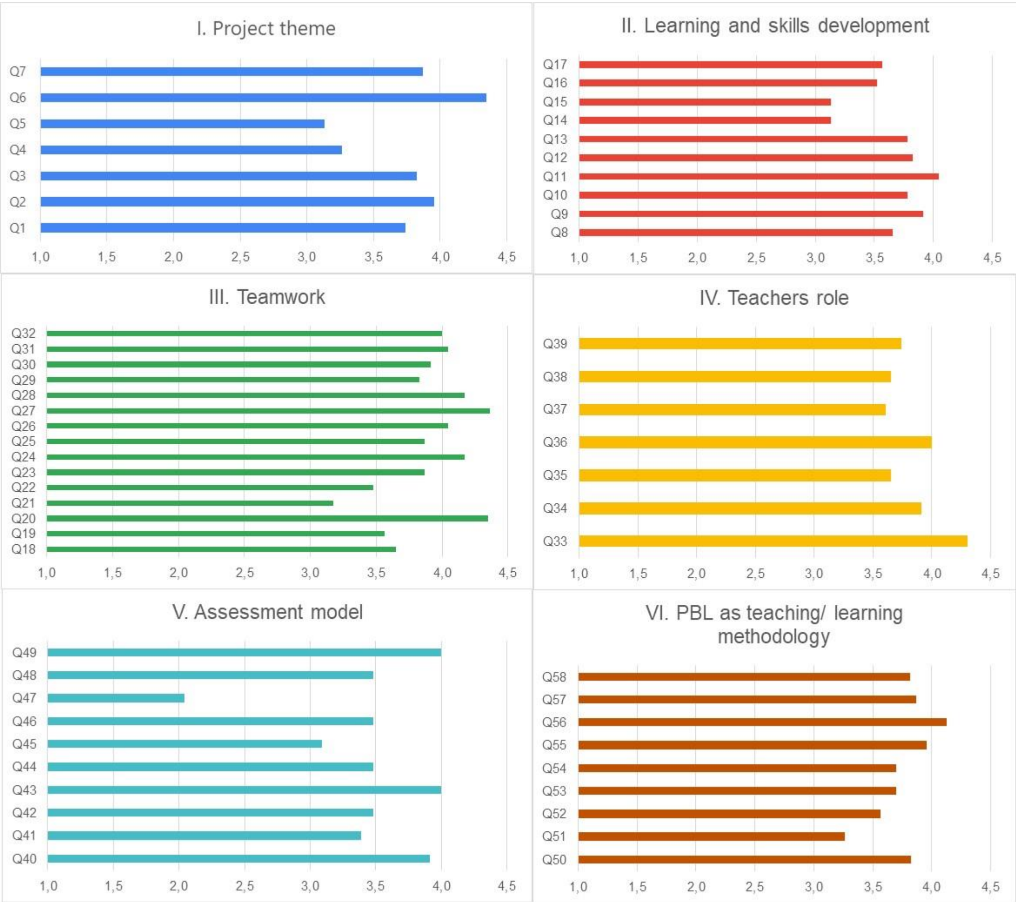


Figure 3. Results of the questionnaire by dimension.

The focus group moderated in the workshop reached more or less the same feedback. Relatively to the teachers' feedback and support, students considered that feedback should be more detailed and the room for the support classes should be near or just one for all teachers to be in the same place. The project and support from the company were good and very useful for the transition of students from academic to professional. Nevertheless, students complained about the distance from the university to the company (the longest was 50 Km). Related to the integration of the courses, students referred to the teams were not balanced due to the different courses between the team members. As in the questionnaire results, students agreed that the peer assessment should be after each milestone, and it should be a weighted average, not an arithmetic average. Team members not participating in meetings should not assess some factors and the assessment should be justified. They also agreed that should be agendas for all meetings, what didn´t happen (Q22 had a low score and it is related to the meetings).

4.2 Companies

The companies that participated in this initiative were, in general, satisfied with this experience. Four of them had no problems starting this project, but one of them had many bureaucratic issues, delaying the project start and creating a lot of stress in the team. The reason, probably, was due to poor communication between engineers that wanted the project and human resources that were demanding a formal protocol, different from the one accepted in other companies. This was also the only company that did not provide feedback about team performance.

Almost all representatives of the companies were in the PBL final presentation moderated by the IP coordinator (online and physically) and gave a very pleasant oral feedback on the teams´ performance. Three gave written feedback, translated here:

1. *Company 4: "My feedback on the project is very positive. The group was very committed and visited the company every week. The proposed solutions seem quite relevant to me and most of them will be effectively implemented. In addition, there was always a concern to listen to employees and to take their suggestions into account, which is highly valued. One of the positive aspects of the project, in my point of view, is the diversity of course in which the students are integrated, which increases the possible areas of action and allows adaptation to any type of problem and industry. One of the aspects that in my opinion could be improved, based on some conversations with the students, is the clarification of some objectives and expectations for the control points. Otherwise, I think the project exceeded expectations."*
2. *Company 1: "In general, we are quite satisfied with the work carried out and that we are incorporating part of the knowledge obtained during the duration of the project into our activity. Naturally, there is room for improvement. We felt that the involvement of part of the group fell short of what was desirable. We consider that the parts of the project relating to the layout of our warehouse and its operation were very well founded, but the lack of understanding on the part of the group that dealt with "product development" was notorious. In this chapter, no control KPIs were suggested as was supposed and contemplated in the project objectives. About the company's relationship with the University of Minho, we have nothing to point out. It has always been a pleasure to work with such an esteemed institution and we will always have the pleasure of participating in new initiatives."*
3. *Company 3: "I feel that not all elements participated in the same way, and I highlight Stud.19 as the most constant and coherent. My overall assessment is very positive, as they understood the challenge and responded. The document they presented to define the RPA will be used by us for their development. As points to improve, in a professional context, there are only two: 1) Management of stakeholders, because their communication with me did not have a defined frequency and structure; 2) Team management, because I felt that the roles were not well defined and the spokesperson figure was not consistent. I reinforce that I give this feedback as a recommendation to increase their professional success and not to reduce the immense work and dedication invested in this project. It only remains for me to thank you, on behalf of the company, for your commitment to us in the development of the professionals of the future."*

The supervisor that provided this third comment from company 3 invited the team and the IP coordinator to present the project results to the unit responsible in the company and discussed with them this same feedback, in a perspective of continuous improvement.

4.3 Teachers

This section presents the feedback from the teachers involved in this PBL in the form of answer to the questions referred in section 2: 1) What went well? 2) What went wrong? And 3) What can be improved?. This feedback was mostly shared by all teachers.

The direct interaction with the industry is, in general terms, one of the undeniable advantages of this PBL edition, which is being reported as an important result of these types of projects (Lima et al., 2017). Besides dealing with real problems, the teams are exposed to some challenges/problems that may not be easily replicated in an academic environment, for example, those related to interacting with industry professionals and obtaining information from the shop floor. Regarding this last aspect, the ability to deal with incomplete and/or scarce (and even contradictory) information is a competence whose development is enhanced. Alongside this, having to present their ideas to middle and upper management was also a challenge and hard to replicate in an academic environment. However, students were able to respond quite effectively to the challenges posed by the open-ended and diverse problems they were given. It was an experience that gave them the opportunity to understand the practical relevance of some of the topics presented in the different courses.

One of the problems identified in this PBL edition was the relatively slow start of the project. The process of forming teams was not trivial because different teams may have students enrolled on different optional course, which was challenging to align the project problems with the learning outcomes that each student should develop in the course. This was very different from other PBL experiences where all team members are enrolled in the same compulsory courses, namely, Lima et al. (2017). Also, in some cases, the first visit to the companies was delayed. Additionally, the number of project milestones and deliverables demanded a high workload for students and teachers.

To accelerate the start of the project, the first visit of each team to the respective company should be scheduled in advance. It is very easy to lose a couple of weeks if this scheduling is only done after the project kick-off session. Also, students' team time management can be improved. Some teams reported little time to work together, due to diverse individual schedules and appointments. Fixing, beforehand, a weekly time slot for the project is something to push for in the next edition. To reduce overload, it is possible to reduce the number of deliverables and create a supervisor role for each team relying on weekly supervisor feedback to keep the project on track. The diversity of deliverables and assessment mechanisms may have been exaggerated and should be simplified in new editions.

5 Conclusion

This paper discussed a case of cooperation between universities and companies based on a Project Based Learning initiative of the Master in Engineering and Operations Management at the University of Minho. In this project, companies entered in the process as a "special" course, providing the physical space and the real problem for students to learn the contents of the courses. In general, it was beneficial for all stakeholders despite the challenges, namely, time to contact companies, appeal to their participation and explanation of the context of this project, relying on companies to provide the necessary means for students. Most of the companies did not find any difficulties and considered this pedagogical experience a success, emerging from here opportunities to meet students.

Students were also satisfied but reported some challenges, being the most highlighted the travel distance to the companies but this seems a small issue attending that the farthest company was at a distance of 50 km and teams choose the companies (this was not imposed by the IP coordinator). The fact that there were members of the same team with different courses was seen negatively by the students. This is interesting because multidisciplinary is typically appreciated and in business reality, it is common to work with professionals with different backgrounds and specialities. The acceptance of this reality is something that should be developed in the students. It is important to notice that there was not any funding for this project, which could be a barrier to this kind of cooperation (Davey et al., 2018).

Nevertheless, all challenges were overcome and this was a worthy project, that must continuously be improved (A.C. Alves et al., 2017), after hearing from the stakeholders. With this, opportunities emerged: for the companies to have a different look to improve their processes, for teachers to be aware of the real problems companies are facing and, finally, for students to know their professional future and meet their potential employers. Limitations of this study are related with small sample size and the lack of generalizations that derived from this. Future work will imply some changes to the organization adopted in this particular edition, namely, better selection of the companies and management of different schedules.

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References

Alves, A. C., Flumerfelt, S., Moreira, F., & Leão, C. P. (2017). Effective Tools to Learn Lean Thinking and Gather Together Academic and Practice Communities. *Volume 5: Education and Globalization*, V005T06A009. https://doi.org/10.1115/IMECE2017-71339

Alves, A.C., Moreira, F., Fernandes, S., Leão, C. P., & Sousa, R. (2017). PBL in the first year of an industrial engineering and management program: A journey of continuous improvement. *International Symposium on Project Approaches in Engineering Education*, *9*, 44–51.

Alves, A. C., & Abreu, M. F. (2021, November 1). Measuring Sustainability and Operational Performance by Engineering Students In University-Business PBL Partnerships. *Volume 9: Engineering Education*. https://doi.org/10.1115/IMECE2021-68673

Alves, A. C., Lopes Nunes, M., & Braga, A. C. (2022, October 30). Empowering Master Students to Pull What They Want to Learn. *Volume 7: Engineering Education*. https://doi.org/10.1115/IMECE2022-94798

Alves, A. C., Moreira, F., Leão, C. P., & Fernandes, S. (2020, November 16). Ten Years of Positive Feedback on Project-Based Learning From First-Year Engineering Students' Perspective. *Volume 9: Engineering Education*. https://doi.org/10.1115/IMECE2020-23212

Alves, A. C., Moreira, F., Carvalho, M. A., Oliveira, S., Malheiro, M. T., Brito, I., Leão, C. P., & Teixeira, S. (2019). Integrating Science, Technology, Engineering and Mathematics contents through PBL in an Industrial Engineering and Management first year program. *Production*, *29*(x), 0–0. https://doi.org/10.1590/0103-6513.20180111

Alves, A. C., & van Hattum-Janssen, N. (2022). *Training Engineering Students for Modern Technological Advancement* (Anabela Carvalho Alves & N. van Hattum-Janssen (eds.)). IGI Global. https://doi.org/10.4018/978-1-7998-8816-1

Araujo, A., & Manninen, H. (2021). Contribution of Project-Based Learning on Social Skills Development. In A. C. Alves & N. van Hattum-Janssen (Eds.), *Training Engineering Students for Modern Technological Advancement* (pp. 119–145). IGI Global. https://doi.org/10.4018/978-1-7998-8816-1.ch006

Barron, B., & Darling-Hammond, L. (2008). Teaching for meaningful learning: A review of research on inquiry-based and cooperative learning. In *Powerful Learning: What We Know About Teaching for Understanding*.

Davey, T., Meerman, A., Muros, Victoria Galan, B. O., & Baaken, T. (2018). *The state of University-Business Cooperation in Europe*.

Dewey, J. (1916). *Democracy and Education. An introduction to the philosophy of education*. Free Press.

Dinis-Carvalho, J., Fernandes, S., Lima, R. M., Mesquita, D., & Costa-Lobo, C. (2017). Active Learning in Higher Education: developing projects in partnership with industry. *Proceedings of INTED2017 Conference*, 1695–1704.

Edström, K., & Kolmos, A. (2014). PBL and CDIO: complementary models for engineering education development. *European Journal of Engineering Education*, *3797*(June 2015), 1–17. https://doi.org/10.1080/03043797.2014.895703

Equipa de coordenação 2022_23. (2022). *Guia do projeto aprendizagem no contexto Project-Based Learning (PBL): Projeto Integrador (PI_MEGO21)*.

Fernandes, S., Mesquita, D., Flores, M. A., & Lima, R. M. (2014). Engaging students in learning: Findings from a study of project-led education. *European Journal of Engineering Education*, *39*(1), 55–67. https://doi.org/10.1080/03043797.2013.833170

Frank, M., Lavy, I., & Elata, D. (2003). Implementing the project-based learning approach in an academic engineering course. *International Journal of Technology and Design Education*, *13*(3), 273–288. https://doi.org/10.1023/A:1026192113732

Graaff, E., & Kolmos, A. (2007). *Management of Change: Implementation of Problem-Based and Project-Based Learning in Engineering*. Sense Publishers.

Helle, L., Tynjälä, P., & Olkinuora, E. (2006). Project-Based Learning in Post-Secondary Education – Theory, Practice and Rubber Sling Shots. *Higher Education*, *51*(2), 287–314. https://doi.org/10.1007/s10734-004-6386-5

Jollands, M., Jolly, L., & Molyneaux, T. (2012). Project-based learning as a contributing factor to graduates' work readiness. *European Journal of Engineering Education*, *37*(2), 143–154. https://doi.org/10.1080/03043797.2012.665848

Kekkonen, M., & Isoherranen, V. (2021). Mechanical Engineering Students Project-Based Learning in OUAS. In A. C. Alves & N. van Hattum-Janssen (Eds.), *Training Engineering Students for Modern Technological Advancement* (pp. 50–68). IGI Global. https://doi.org/10.4018/978-1-7998-8816-1.ch003

Kilpatrick, W. H. (1918). The project method. *Teachers College Record*, *19*(4), 319–335.

Knoll, M. (1997). The Project Method: Its Vocational Education Origin and International Development. *Journal of Industrial Teacher Education*, *34*(3), 59–80.

Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of the literature. *Improving Schools*, *19*(3), 267–277. https://doi.org/10.1177/1365480216659733

Lima, R. M., Mesquita, D., Dinis-Carvalho, J., & Sousa, R. M. (2015). Promoting the Interaction with the Industry through Project-Based Learning. *Seventh International Symposium on Project Approaches in Engineering Education*.

Lima, Rui M., Dinis-Carvalho, J., Sousa, R., Arezes, P., & Mesquita, D. (2018). Project-Based Learning as a Bridge to the Industrial Practice. In L. A. Viles E., Ormazábal M. (Ed.), *Closing the Gap Between Practice and Research in Industrial Engineering. Lecture Notes in Management and Industrial Engineering* (pp. 371–379). Springer. https://doi.org/10.1007/978-3-319-58409-6_41

Lima, Rui M., Dinis-Carvalho, J., Sousa, R. M., Alves, A. C., Moreira, F., Fernandes, S., & Mesquita, D. (2017). Ten Years of Project-Based Learning (PBL) in Industrial Engineering and Management at the University of Minho. In A. Guerra, R. Ulseth, & A. Kolmos (Eds.), *PBL in Engineering Education* (pp. 33–51). SensePublishers. https://doi.org/10.1007/978-94-6300-905-8_3

Lima, Rui M, Carvalho, D., Assunção Flores, M., & Van Hattum-Janssen, N. (2007). A case study on project led education in engineering: students' and teachers' perceptions. *European Journal of Engineering Education*, *32*(3), 337–347. https://doi.org/10.1080/03043790701278599

Lima, Rui M, Dinis-carvalho, J., Campos, L. C. De, Mesquita, D., Sousa, R. M., & Alves, A. (2014). Projects with the Industry for the Development of Professional Competences in Industrial Engineering and Management. *Proceedings of Project Approaches in Engineering Education (PAEE2014)*.

Lima, Rui Manuel, Dinis-Carvalho, J., Sousa, R. M., Arezes, P., & Mesquita, D. (2017). Development of competences while solving real industrial interdisciplinary problems: a successful cooperation with industry. *Production*, *27*(spe). https://doi.org/10.1590/0103-6513.230016

Marinho, J. E. T., Freitas, I. R. M., Leão, I. B. dos S., Pacheco, L. O. C. S., Gonçalves, M. P., Castro, M. J. C., Silva, P. D. M., & Moreira, R. J. S. (2022). Project-Based Learning Application in Higher Education. In Anabela Carvalho Alves & N. van Hattum-Janssen (Eds.), *Training Engineering Students for Modern Technological Advancement* (pp. 146–164). IGI Global. https://doi.org/10.4018/978-1-7998-8816-1.ch007

Mills, J. E., & Treagust, D. F. (2003). Engineering education - is problem-based or project-based learning the answer? *Australasian Journal of Engineering Education*, *3*, ISSN 1324-5821. https://doi.org/10.1108/13552540210420989

Pecore, J. L. (2015). From Kilpatrick's Project Method to Project-Based Learning. In M. Y. Eryaman & B. C. Bruce (Eds.), *International Handbook of Progressive Education* (pp. 155–171).

Pereira, M., & Barreto, M. (2016). PBL in school of Engineering of Lorena at the University of São Paulo: Lessons learned and challenges. In Rui Manuel Lima, E. de Graaff, A. C. Alves, A. Menezes, D. Mesquita, J. Dinis-Carvalho, L. Bettaieb, N. van Hattum-Janssen, N. Costa, R. M. Sousa, S. Fernandes, & V. Villas-Boas (Eds.), *Proceedings of the PAEE/ALE'2016, 8th International Symposium on Project Approaches in Engineering Education Education (PAEE) and 14th Active Learning in Engineering Education Workshop (ALE)* (pp. 174–181).

Powell, P., & Weenk, W. (2003). *Project-Led Engineering Education* (Vol. 53, Issue 9). Lemma Publishers. https://doi.org/10.1017/CBO9781107415324.004

Robinson, J., & Beneroso, D. (2021). Project-Based Learning in Chemical Engineering. In A. C. Alves & N. van Hattum-Janssen (Eds.), *Training Engineering Students for Modern Technological Advancement* (pp. 1–19). IGI Global. https://doi.org/10.4018/978-1-7998-8816-1.ch001

Thomas, J. W. (2000). *A review of research on Project-Based Learning*. http://www.bie.org/research/study/review_of_project_based_learning_2000

Digging into students’ perception about peer and self-assessment

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Abstract

This proposal follows on from our previous work, in which we presented teachers' and students' perspectives on self-assessment and peer assessment. These assessment methods were presented as valuable options for competence-based assessment. This second part aims to explore local students’ perception of self and peer assessment in active learning environments, focusing on their strengths and weaknesses. The study uses small-scale qualitative research methods based on questionnaires and interviews to collect data from undergraduate and master’s degree students. The findings suggest that students perceive self and peer assessment as valuable tools for learning, but there are concerns about the reliability and validity of student-based assessment. The need for specific training in formative assessment and previous experiences have been pointed out as two of the most relevant elements to overcome the concerns.

Keywords: Assessment in active learning; Self and peer assessment in engineering; Competencies assessment.

1 Introduction

Student based assessment has been stated by several authors as convenient or, moreover, as a compulsory, when active learning strategies are used, as their own contributions can be deeply relevant in evaluation processes (Mc Donald & Savin-Baden, 2004). Self-assessment and peer assessment have been proved to be essential tools in active learning environments, with its different strategies. Moreover, the process of giving and receiving feedback has long time been accepted as an important aspect of student learning (Kolmos & Hogland, 2007) as this process provides students with valuable skills for professional contexts and trains them for future learning.

There are works exploring students’ perception of self and peer assessment, highlighting both strengths and concerns. Patton (2012) concluded that the students’ proposed model of peer assessment addressed their concerns with current peer assessment practices by increasing formative feedback and limiting its potentially damaging impact as a summative exercise. Planas et al (2014) detected different perception based on previous experiences, with first year students being more reluctant to these kind of assessment methods while students with prior experience show grater predisposition and interest likely forming part of their future professional work. One of the expected outcomes of this study is to confront the conclusions of these previous studies with the particularities of our own students. There is no attempt to draw conclusions that can be extrapolated, but rather to gain a deeper understanding of the context of the situation at a local level.

In the first part of this study (Romá, Ballester-Berman et al, 2022) a reflection on the advantages of self and peer assessment within engineering assessment was made in the context of the University of Alicante, but also analysing the risks involved (lack of maturity, assigning too high grades…). This feeling of risky activity was presented as especially dangerous when it must be used by teachers who are reluctant to its use. Analysis of collected assessment data and questionnaires addressed to both teachers and students was used to provide an insight to their opinion about these assessment methods. This previous study showed an overall picture of students' and teachers' perspective about student-based assessment, including a review of their 'feelings' when using this kind of assessment methods. Besides, a deeper analysis was included trying to find out, by means of comparisons of data obtained from 2008 between the marks (and general opinion) provided by teachers to their students with the marks obtained by self-assessment and peer assessment in different engineering courses.

As the main reason showed (mainly) by reluctant teachers is the lack of confident in the fairness of students when assessing their own work (especially because students can over-rate themselves), one of the main goals of this previous study was to determine if there is, or not, consistency between the marks, to detect if giving part of the responsibility of the evaluation to the students will imply sacrificing the reliability of the process.

2 Methodology

This work is being developed under the framework of a two-year network project of the University of Alicante pursuing improvement of quality and innovation in higher education by means of specific learning experiences. The main goal of the second year of the project is to explore the risks and strengths of self and peer assessment from students' perspective together with their feelings in front of those strengths and dangers from a local context, as explained in following sections. It has to be clear that we are not pursuing a strict research, but to have an overall picture about the aim of our students when they are asked to be an active part of the evaluation process, and how to increase their confidence level on these assessment methods.

2.1 Context of the study

While the comprehensive set of data is included in the previous report, the most significant results are going to be repost, just as an example for having a complete context, and taking only into account the marks (being aware that the information that can be obtained is much more complex than just mere numbers), the difference between the self-assessment marks and the final mark (0-10 scale) is displayed for about 750 students for a 10 years gap, together with the average of this difference per year, and is presented in Figure 1.

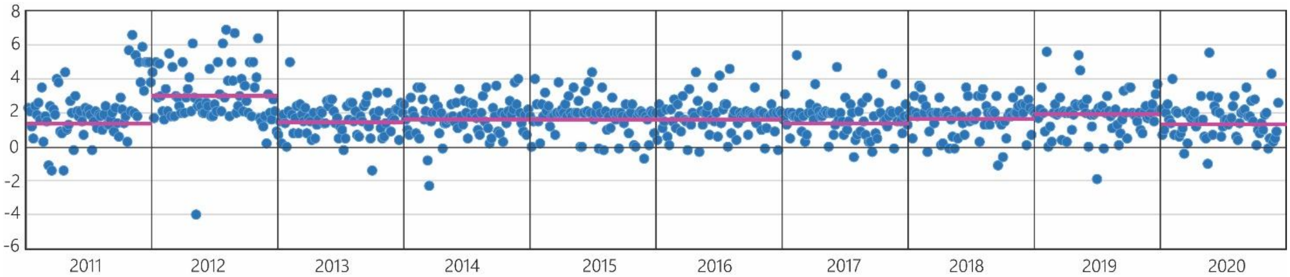

Figure 1. Numeric difference between self-assessment and final mark of a first-year engineering course. Pink bars indicate the average difference per year.

Even though this data is obtained from a first year engineering course, with students that are supposed to be less mature, there is clear consistency in the results. There is a quite stable offset of about two points between the marks (0-10 grading scale).

When considering peer assessment, similar conclusion can be obtained as shown in figure 2, comparing peer assessment and teacher's marks. In this case it is interesting to consider that, contrary to reluctant teachers' opinion, there is not a general tendency to over-rate if the teacher mark is taken as a reference. Not only there is a high degree of correlation but in almost half of the cases, students are marking their peers with a more severe criterion than the teacher.

The analysis of the data included in the first part of this study showed a clear consistency with the results stated by Alias, Masek et al (2014), who conclude that students tend to judge themselves as being like their peers which are higher than that judged by the teacher. Interestingly also, students tend to judge themselves better than how their peers judge them. It can be concluded that student-based assessment does provide information on self and peers which may not agree with what is perceived by a teacher. Notwithstanding, the possible disagreement will be less relevant when students have high ability in the assessment process (Lew, Alwis, and Schmidt, 2010), so a proper training in student-based assessment is needed.

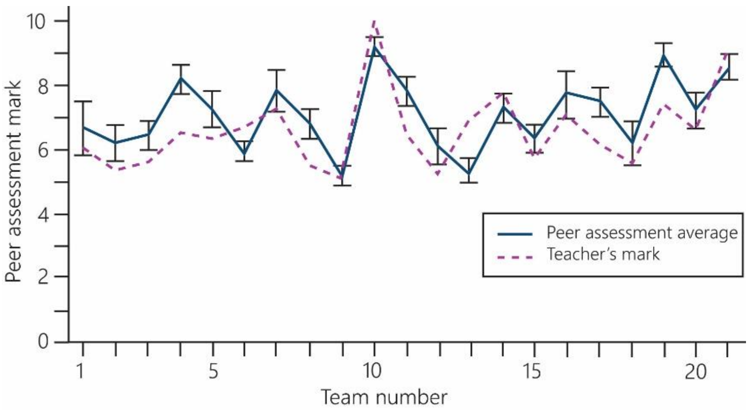

Figure 2. Comparison between peer assessment and teacher's marks from a 3rd year engineering course.

As the set of data collected comes from evaluation results (numerical data) and questionnaires sent to both teachers and students, the second part of the work pursues gathering information only from students' opinion and their relationships with their personal context, exploring the presence of meaningful correlations.

2.2 Collection and analysis of data

The main source of information to gather students' perspective in front of self and peer assessment have been a set of questionnaires sent to students between 1st and 4th year courses from Sound and Image in Telecommunication Engineering (SITE) and Biomedical Engineering (BE) degrees in the University of Alicante Polytechnic School and from the Master´s degree on Education Research. 60 students have fulfilled the form, so, even no statistically sounding conclusion can be made, relevant information can be obtained to understand students' perspective about their relationship with students-based assessment. It is important to note that the scope of the project is limited to obtaining information from the local context and its results may not be extrapolated to other institutions.

The questionnaire is composed of 23 multiple choice questions (6 about assessment in general, 9 about self-assessment and 8 about peer assessment), and one open answer question. A summary of the questions is presented in table 1.

Table 1. Summary of the questionnaire sent to the students.

	Question	**Answer type**
Introducto	Highest course enrolled	1st - 4th grade
	The assessment must be objective	agreement level
	Preferred assessment model (summative, formative, mixed, without opinion)	assessment type

	I have used self-assessment	number of times
	I have used peer assessment	number of times
	Year(s) in which peer or self-assessment is used	1st - 4th grade
self-assessment	I think self-assessment is interesting	agreement level
	Self-assessment generates better learning experiences than exams	agreement level
	Self-assessment is an individual reflection tool but without effect in the marks	agreement level
	Self-assessment is interesting and must affect the marks	agreement level
	Self-assessment must not be used in first years (lack of maturity)	agreement level
	Students over-rate ourselves with self-assessment	agreement level
	Students are able to justify in a mature way the self-assessment	agreement level
	Students are aware about the confidence self-assessment implies	agreement level
	Best students have a higher level of self-criticism that is reflected in self-assessment	agreement level
peer assessment	I think peer assessment is interesting	agreement level
	Peer assessment generates better learning experience than exams	agreement level
	Peer assessment is an individual reflection tool but without effect in the marks	agreement level
	Peer assessment is interesting and must affect the marks	agreement level
	Peer assessment must not be used in first years (lack of maturity)	agreement level
	Students over-rate ourselves with peer assessment	agreement level
	Students are able to assess our peers in a reflexive and mature way	agreement level
	Students make a non-aggression agreement with peer assessment	agreement level

Without the goal of performing a deep qualitative data analysis (QDA) due to time and people restrictions of the project framework, we have performed a down-scale QDA version. In order to find themes and patterns in the collected answers, the process of organizing qualitative data (non-numeric and conceptual information) has been crucial allowing to get a fast and, as clear as possible, visual overview of the results. Figure 3 presents a sample of the way in which the information has been organized, using tags and colours, in the search of patterns that could be useful for the analysis.

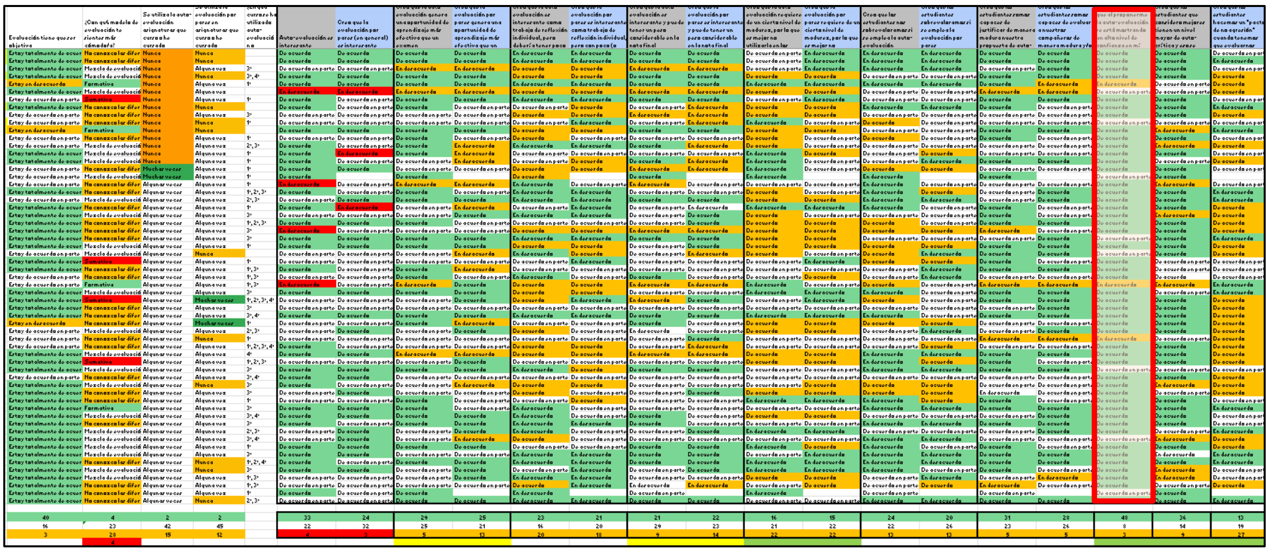

Figure 3. General screenshot of one of the spreadsheets used to generate visual information (white header: context; grey heather: self-assessment; blue heather: peer assessment). The highlighted column is (as an example) the one with the most significant level of agreement.

3 Results

As can be seen in Table 1, the questions are divided in three categories (plus an open answer one). The first group intended to have an idea about the background of students with assessment methods in general and with student-based assessment in particular. The second and third ones include similar questions about self-assessment and peer assessment. We have used these questions to extract information about the different aspects. In this report we are going to present the following ones:

- Impact of previous experiences.
- Analysis of differences and similarities between assessment strategies.
- Evidence related to the assessment strategies.

3.1 Impact of previous experiences

One of the (obvious) differences noticed is that, in accordance with Planas et al. (2014), most of the students who have not used students-based assessment give negative answers to the questions related with the benefits of this type of evaluation. The most paradigmatic answer in this sense refers to agreeing in the fact that both self-assessment and peer assessment must have none or little influence in the final marks. The fact that most of them affirm not knowing the differences between formative and summative assessment methods points towards the need of providing information about evaluation to students during their first months as university students. It is noticeable that 70% of the near 50% of students that states not knowing the difference between summative and formative assessment have had experiences with formative assessment. These figures remark the lack of knowledge about evaluation methods that even experienced students have.

3.2 Analysis of differences and similarities between assessment strategies

As many of the questions are basically replicated related to self-assessment and peer assessment, it is interesting to find out if students have the same or different opinion when comparing these two kinds of evaluation.

Even though there is a general perception that both evaluation types generate better learning experiences than exams (students are often not in favour of exams), while an 8% of students disagree with this sentence when self-assessment is involved, there is a 22% in the case of peer assessment. When considering if student-based assessment must have a noticeable effect in the final marks, there is a 15% of disagreement in self-assessment and a 24% in peer assessment. As will be corroborated by other questions, students show a clear tendency to be more confident in self-perception than those that come from their peers.

When searching for similarities, there are two questions in which the answers are almost identical. 37% of students think that none of these methods must be used in first course. Besides, 92% of students state that they are capable to justify in a mature way both self and peer assessment. It is noticeable that almost 50% of students affirm making a non-aggression agreement when assessing their peers. This high number points against the self-perception of being able to evaluate in a mature and reflective way.

3.3 Evidence related to the assessment strategies

In this section we would like to highlight the most significant comments made by students (translated from Spanish to English trying not to change students' writing style) when asked to point out what circumstances are (or would have to be) in place for self-assessment or peer assessment to be (or should be) used as relevant (weighted for the final mark) methods in subjects you take or have taken. These comments can be organized in several categories:

- **Matureness and self-perception**:

"It would be fine under certain conditions for certain students in particular, with maturity and well-measured self-criticism. I think that the problem may be in students who, for whatever reason, undervalue themselves and it may be the case that having made a great effort they are not able to see it because of this self-perception in which they value themselves less, and vice versa, of course, students who are more narcissistic may not make a great effort but consider that they deserve a higher mark than they should in reality."

"I consider the self-assessment to be interesting in terms of reflecting on what we have learnt throughout the course and how much knowledge we have gained, and I also consider the peer assessment to be useful to be able to observe our mistakes and errors in a delivery or an exam."

- **Relationship between students**:

"If the course is based on public presentations and we had to evaluate our classmates, for example, knowing that the teacher would review the marks we had given in both the self-assessment and the peer assessment."

"In a good environment, where peer review is not influenced by whether a colleague doesn't like me and his or her viewpoint will be very bad, just as if he or she likes me, his or her viewpoint will be quite good."

"There must be no relationship between the students or no competition between them."

"Students must, always, justify the marks they are proposing."

- **Methodology used in courses**:

"Especially in the more practical subjects, since in the end the overall learning process is based on the time it takes to assimilate the new tasks. In many cases, the actual learning process in terms of integration into the workplace is often not exploited to any great extent."

"Those subjects in which the work of the classmates is relatively similar. Having done this work yourself, you can assess the work of others much better."

- **General comments about students-based assessment**:

"By evaluating ourselves we become aware of our own failures, which is very important, as teachers often treat you in a derogatory manner for not knowing something, without considering that we are not memorisation machines and even less so if things are taught badly."

"I think that if self-assessment were present in the subjects, everyone would be more attentive to the classes and would dare to ask questions, because that is what their mark is going to be about and not about an exam in which many more factors than your knowledge of the subject influence."

"Both models must always be based on a rubric capable of effectively assessing the contents of the subject/project being analysed."

"These methods must only be use for marking when student's mark is a fine line between passing or failing the course."

3.4 General analysis

This section will highlight the most relevant aspects obtained from the analysis of the answers given by the students. It is important to emphasise once again that, given that 60 responses were received, the aim is not to generate statistically significant information, but rather to obtain general knowledge about the position of the students in our context in relation to the assessment methods considered.

It has been seen as essential for students to be aware of the differences between the different types of assessment, as there has been evidence of a significant lack of knowledge in this respect, which generates a certain level of mistrust of methods other than summative assessment, to which they are largely accustomed. This can be improved with some previous training, giving positive feedback, and explaining that peer assessment involves learning for students and promotes a sense of personal responsibility and motivation, as stated by Topping (2009). This will also help to minimise the feeling that student-based assessment should not be used in the first semesters. There is general agreement that these types of assessment have benefits in improving learning progress, but there is a noticeable level of rejection of their use as part of the final mark, especially among students who have had no previous experience. It is curious that while several students comment that these methods are useful for detecting problems, there is no comment on their effectiveness in detecting what is being done well. This is in line with the lack of knowledge about formative assessment. Again, the need of training in assessment for the students is crucial to optimize its benefits and reduce the reluctance level.

If the assessment has marks associated, reports justifying these marks are compulsory. The use of rubrics is seen as key to having a common criterion.

Generally speaking, there is greater confidence in self-assessment than evaluation performed by peers. In the specific case of peer assessment, two aspects stand out clearly. On the one hand (again in the case of students with no previous experience), the need for peer assessment not to be influenced by the opinion of others is evident. On the other hand, there is a broad consensus that peer assessment is particularly useful for projects and practical work in general, and especially in cases where all students or working groups are solving the same problem or, at least, a similar one.

Although there are no aspects that generate alarming levels of rejection, there are two cases that deserve to be mentioned.

On the one hand, there is a level of rejection of using these methods in the first years (showing a widespread belief that a sufficient level of maturity is necessary).

On the other hand, there is also a certain level of rejection of peer assessment having a significant effect on the final mark. This last aspect can be understood with the comments from the open answer question as mentioned in the next section (relationship between students). It is important to mention that most of the students who are against peer assessment being considered in the final grade are those who have had no previous experience of peer assessment.

4 Conclusion

A set of data obtained during more than 10 years of evaluations and marks, together with questionnaires and interviews with colleagues and students have been used to gather information about self-assessment and peer assessment. In a first analysis, the consistency between teachers' and students' evaluation was stated, in accordance with results found in the literature.

A second part of the study, presented in this paper, has been carried out to find out the level of acceptance of student-based evaluation by our students, the aspects that they see as most positive and those that cause them most distrust.

The need for training in student-based assessment specially (but not limited to) during the first semesters has been detected as a key aspect to increase the level of acceptance or confidence in these evaluation methods.

Having previous experience has been seen as a fundamental element in reducing one of the most feared aspects by students: the influence of personal peer opinion on the outcomes of peer assessment.

5 Acknowledgment

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6 References

Alias, M., Masek, A. et al (2014). Self, peer and teacher assessments in problem based learning: are they in agreement?. Proceedings of the 4th world congress on technical and vocational educatinal and training (WoCTVET), Malasya, November 2014, 309-317.

Kolmos, A. and J.E. Holgaard, (2007). Alignment of PBL and assessment.1st International Conference on Research in Higher Education. Honolulu: American Educational Research Association, 1-9.

Lew, M. D. N., Alwis, W. A. M. and Schmidt, H. G. (2010). Accuracy of students' self-assessment and their beliefs about its utility. Assessment and Evaluation in Higher Education, 35, 135–156.

MacDonald, R.F. and Savin-Baden, M. (2004). "A Briefing on Assessment in Problem-based Learning," LTSN Generic Centre Assessment Series. Available on the Higher Education Academy's Resource Database at: www.heacademy.ac.uk/resources.asp?process=full_record&section=generic&id=349

Patton, C. (2012) 'Some kind of weird, evil experiment': student perceptions of peer assessment, Assessment & Evaluation in Higher Education, 37:6, 719-731, DOI: 10.1080/02602938.2011.563281

Planas, A., Feliu, L., Fraguell, R. M., Arbat, G., Pujol, J., Roura-Pascual, N., Suñol, J. J. & Montoro, L. (2014) Student perceptions of peer assessment: an interdisciplinary study, Assessment & Evaluation in Higher Education, 39:5, 592-610, DOI: 10.1080/02602938.2013.860077,

Romá, M., Ballester-Berman, J. D. et al (2007). Strenghs and dangers fo self and perr assessment in engineering learning: Teachers' and students' perspective. Proceedings of the 3rd international Conference on Actice Learning in Engineering Education,Alicante, Spain, June 2022, 38-45. DOI: https://doi.org/10.5281/zenodo.6924152

Topping, K. 2009. "Peer-assessment." Theory into Practice 48 (1): 20–27.

Using a wireless power transfer project to enhance the understanding of the Electromagnetic Theory in a modeling and simulation framework

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Abstract

The article describes a wireless power transfer (WPT) project carried out by undergraduate engineering students at Insper as a context for consolidating the learning of Maxwell's equations in the Electromagnetism and Waves course. The project was aimed at 4th semester students of the Computer, Mechanics, and Mechatronics engineering programs, and was intended to be carried out in a modeling and simulation framework, in which students designed, simulated, physically implemented, and validated the circuitry that allows power to be transferred wirelessly between a pair of magnetically coupled coils, a sufficiently complex, current, and real-world application.

Using the Python language, students were able to simulate output results and validate the model against measurements, adjusting variables with higher uncertainty to obtain a valid model from which conclusions were drawn concerning technical issues or possible future applications.

To engage the students, a contest was held in which the winning group was the one that transmitted more power over a greater distance. Results show that 87% of students found the project completely aligned with the course theoretical content, 62% declared to have learned a lot more during the project, and 76% found WPT a very interesting subject matter for deepening their learning of electromagnetism.

Keywords: project-based learning; modeling and simulation; WPT; electromagnetism.

1 Introduction

Electromagnetism has always been a challenging subject for both students and teachers. Maxwell's equations, unarguably elegant and sophisticated, are highly abstract and require a range of practical applications and real-world examples to be correctly understood and internalized. The traditional teaching of electromagnetism has been mainly through lectures, laboratory scripts and demonstrations (Rosenbaum et al., 1990). Frequently, well-structured problems like those found on textbooks like (Halliday et al., 2014), in which students deal with puzzles of the type "given this, find that" are used to enhance student's comprehension. Less frequently though, engineering and science courses make use of project-based learning approaches, like in (Holubova, n.d.), (Cutri et al., 2022), (Cossovich, 2020) and others, or experiments to deal with "alternative ideas" students may have concerning electromagnetics (Seroglou et al., 1998).

The devise of projects in which students could apply acquired knowledge in an ill-structured manner has been a central goal in the design of the new engineering courses at Insper, in Sao Paulo. Since 2016, faculty has been using project-based learning in the Electromagnetism and Waves discipline with mixed results. Aiming at the enhance of autonomy, the first versions of project specifications let students choose whatever product, machine, or experiment they liked. The only requirement was that at least one of Maxwell's equations were to be used in order to explain the behaviour of the chosen apparatus.

Initial results showed that students engaged in making devices/experiments to work, often without any modeling or simulation of circuits, validation, or prediction of results. Youtube channels were often used as a basis for building prototypes and making them work, although a great number of students were unable to explain how they worked in terms of scientific reasoning. This finding revealed a more maker-type mentality rather than that of an engineer or a scientist, which was not desirable. In a second attempt, faculty proposed a different approach: to give students a subject matter to be worked with, certainly diminishing their level of autonomy and, consequently, their intrinsic motivation (Black & Deci, 2000), although students were still autonomous concerning the design of parts and components of the project. On the other hand, the lesser motivation was somehow compensated for with the devise of a contest in which students could compete for creating the best solution for that given problem. The chosen subject matter for this new round of projects was Wireless Power Transfer (WPT), a topic that has come back to the picture since 2007, when an MIT research group was able to wirelessly transmit about 60 W of power over a distance of 2 meters with 45% efficiency (Kurs et al., 2007).

It seemed that WPT encapsulated a set of positive characteristics searched for by faculty, such as: i) it was based on a sufficiently complex model that could be used in a modeling and simulation framework, ii) it was a current topic, iii) it had real-world application, and iv) it matched a great deal of the covered content, allowing students to connect learned subjects with an engineering application. It is important to mention that the first part of the course was given in a traditional way, making use of lectures and well-structured exercises to provide students with the basic knowledge needed to the understanding of the project.

In this article, we describe the experience in which 118 engineering undergraduate students, grouped in 3 or 4, were able to build a resonant circuit with two magnetically coupled coils, modelled and simulated using lumped circuit theory (Bou et al., 2012), and implemented in Python language. The circuit, which was also physically implemented, resembles an AC transformer without an iron core, whose model students learned before starting the project (El Hage et al., 2021). Because of the high cost of electronic power inverters, students were instructed to use a symmetric quadradic voltage source, built out of a half-bridge circuit (Khemkhaeng et al., 2022) in order to properly feed the primary coil (transmitting coil), and whose simulations using AC analysis were proven to be accurate (El Hage, 2022).

Students were instructed to use an AC transformer model with a capacitor in series with the primary coil and another in parallel with the secondary coil, constituting resonators for wirelessly transferring power from a DC source to a load resistor or whatever load they chose to feed. The main learning objective of the project was to make students capable of applying recently learned knowledge in a complete cycle of design, simulation, and implementation of a real-world application, contributing not only to a deeper understanding of the subject matter, but also to experiencing engineering in its very foundation, i.e., the use of models to explain and predict complex phenomena.

2 Technical details of the project

Students were given precise instructions on what to be accomplished in terms of theoretical and practical deliverables. To maintain a certain level of autonomy as a drive for intrinsic motivation (Black & Deci, 2000), students were required to design not only coil parameters, such as size, geometry, number of turns, and type of wire, but also the capacitances and frequency of operation of the circuit. They were allowed to use software that estimated inductance given material and geometry parameters.

The circuit being modelled by students is composed of a pair of magnetically coupled resonators, comprised of one coil connected to a series capacitor in the transmitter and a second coil connected to a parallel capacitor in the receiver, as shown in Figure 1. For simplicity, we suggested students to use the same constructive parameters for both resonant coils and capacitors. The circuit and modeling are based on (El Hage, 2022).

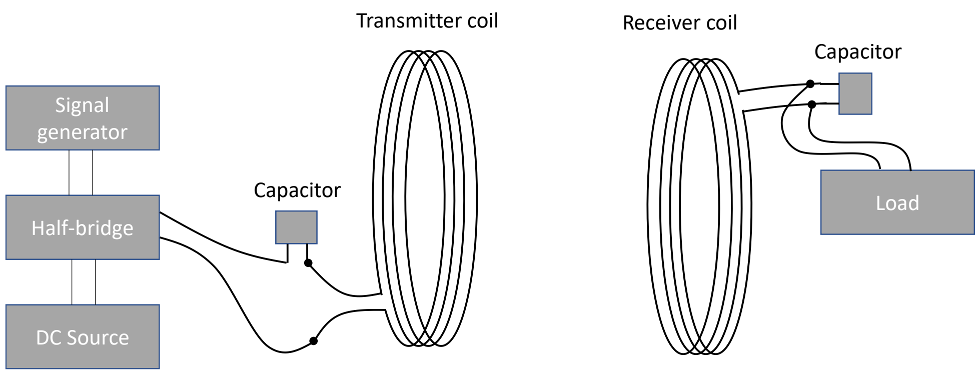

Figure 1. WPT circuit, composed of a pair of magnetically coupled resonators.

The model used for simulating the WPT circuit is the transformer model (El Hage et al., 2021) shown in Figure 2, in which each coil is modelled as a series connection of a self-inductance, a mutual inductance and a parasitic resistance. This model is analysed beforehand in the theoretical part of the course, with which students calculated currents and voltages for different parameters.

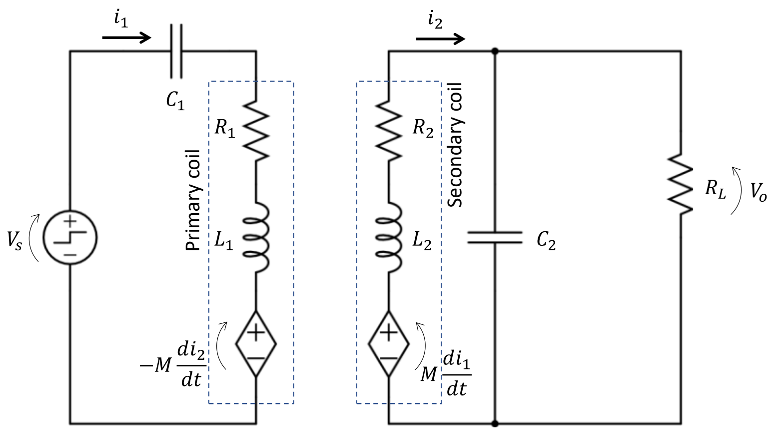

Figure 2. Circuit model for the WPT circuit show in Figure 1.

In Figure 2, V_s represents a PWM power supply with a duty cycle of 50%, comprised of a standard half-bridge circuit powered by two DC sources: a low power source that powers the control circuit, and a medium power source for powering the transmitting coil in low frequency. It is important to mention that the design of the AC power supply was not a project requirement, being suggested that students used the circuit shown in (El Hage, 2022).

For the power electronics to be inexpensive and simple, we chose a standard half-bridge current amplifier that feeds the transmitting coil with a square voltage signal in low frequency, resulting in lower parasitic resistances due to reduced skin effect, attaining higher efficiency for standard wires. We considered electronic components that function in frequencies up to 100 kHz because they were cheaper and easier to find compared with those in the range of MHz.

3 Simulation, implementation, and validation

Students were given leeway to design their coils acknowledging that the coupling coefficient is higher for larger coils, given a certain distance. Using a digital LCR meter, they were able to measure real inductance and choose capacitors for the desired frequency (up to 100 kHz). Figure 3 shows the pair of coils that were built by a group of four students. The physical structure of the coils was made of laser-cut wood. The wires were selected for low parasitic resistances, which were also measured using the LCR meter at the operating frequency.

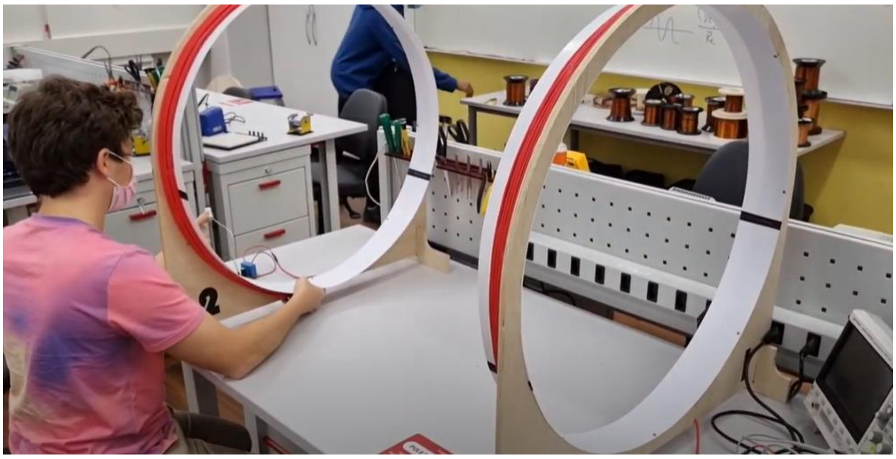

Figure 3. Physical setup for the WPT circuit shown in Figure 1 made by one of the groups.

The WTP circuit simulations conducted by the group exhibit the WPT characteristic behaviour, which is illustrated in Figures 4 and 5. For a given load ($R_L = 1000\Omega$), the frequency at which maximum power is delivered varies with distance between coils, and lower values of k mean larger distances. As shown in Figure 5, efficiency decreases considerably for larger distances (lower values of k), being the higher efficiency always attained at the natural resonance frequency of the circuit (5 kHz).

Voltage on the secondary coil can be easily measured through an oscilloscope, validating the model against measurements. Several groups had to adjust parasitic resistances in order to reduce error between simulations and measurements, given the high uncertainty of these parameters.

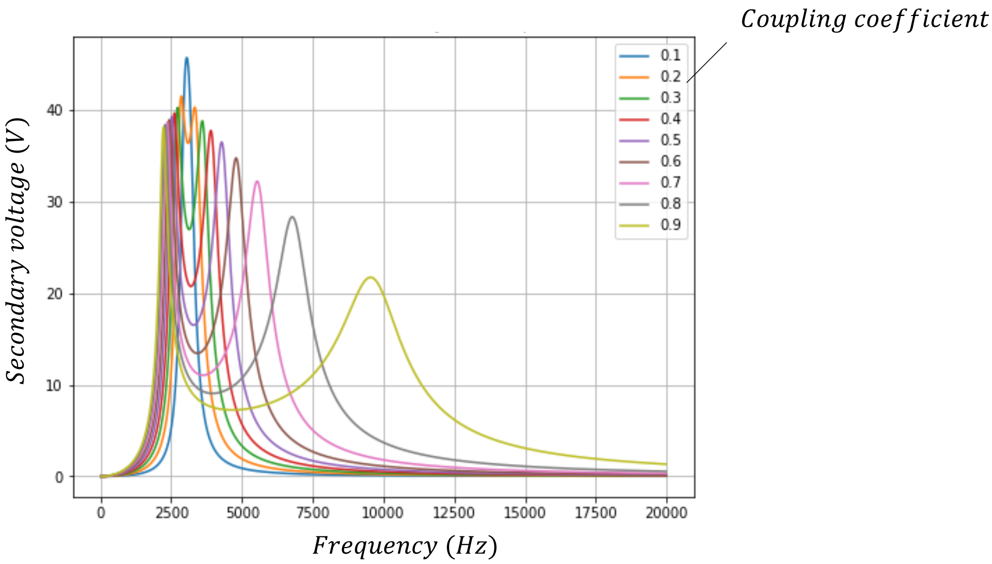

Figure 4. Simulation of load voltage depending on k factor and frequency.

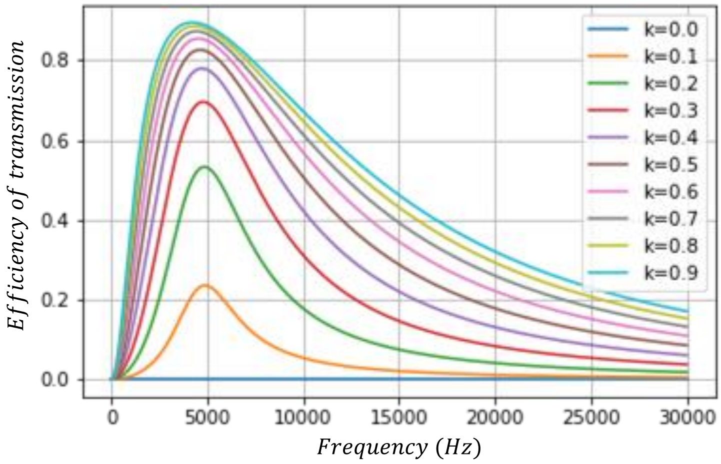

Figure 5. Simulation of transmission efficiency depending on k factor and frequency.

As mentioned before, students were given the freedom to select coils, capacitors, loads, frequency, and independent sources for feeding the half-bridge circuit and the primary coil. The winning group (Figure 6) was able to transmit 8.5 W at 33 cm of distance, using a pair of coils with 45 cm of diameter, and an independent power source. Once they understood, through simulation, which variables were the most significant to increase the transmission of power, even with lower efficiency, they were able to adjust previous parameters in order to increase power and distance at the same time.

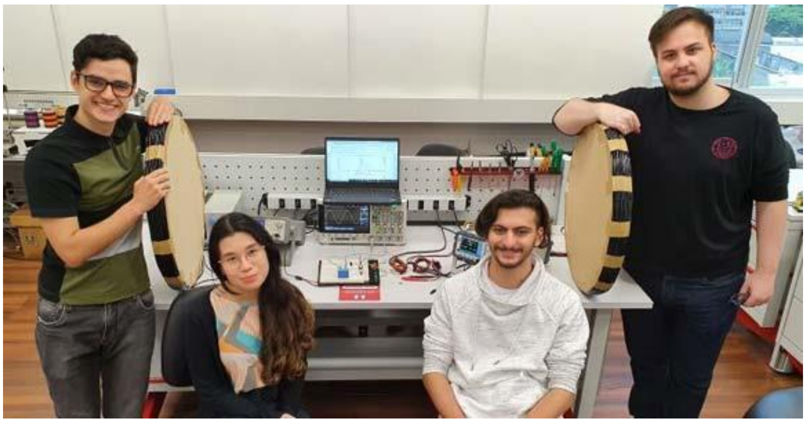

Figure 6. The wining group, delivering 8.5W at 33 cm.

4 Results and Conclusion

The main objective of the article was to describe a complete cycle of modeling and simulation of a WPT project for undergraduate engineering students as a context for applying recent learned content in an engineering framework. In a survey conducted with 118 students after the project was submitted (with only 36 respondents), 62.2% of the students found computational simulations to be very useful for understanding how the circuitry worked. Additionally, 75.7% found the WPT theme to be very interesting and motivating for enhancing their understanding of the subject matter.

62.2% of the students reported that they learned a lot more because of the project, and 86.5% asserted that there was a complete alignment between the theoretical part of the course and the project, mainly because the transformer model was very versatile and flexible for both the theoretical and the practical parts of the course.

Concerning the time frame of the project, 51.4% of students stated that 4 weeks were insufficient for finding more elaborate conclusions about the project. Besides that, faculty observed that 90% of the groups delivered all minimum required simulations and assemblies, in addition to drawing consistent and elaborate conclusions about the results. Figures 7 to 12 detail all questions and answers of the survey form.

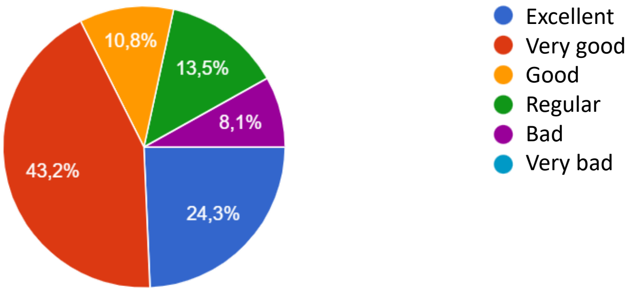

Figure 7. Question: what was your general impression of the project?

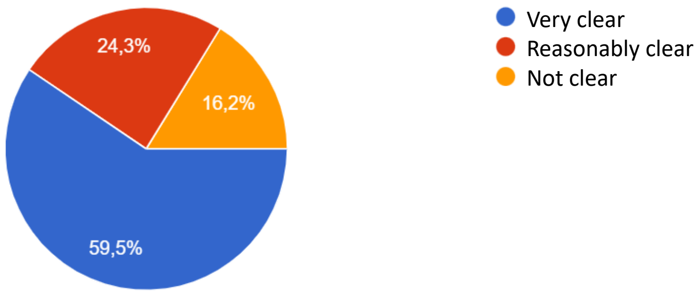

Figure 8. Question: Were the project instructions clear?

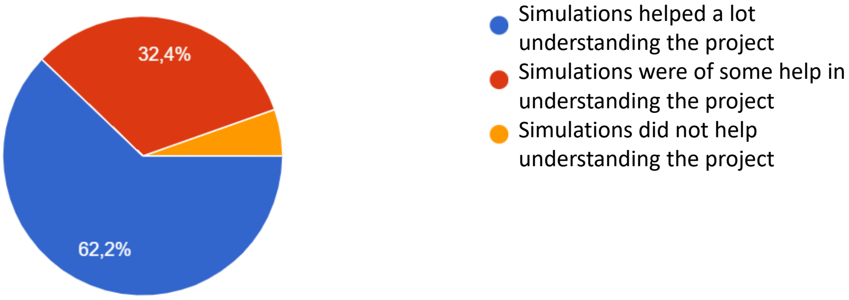

Figure 9. Question: Did simulations help in understanding the project?

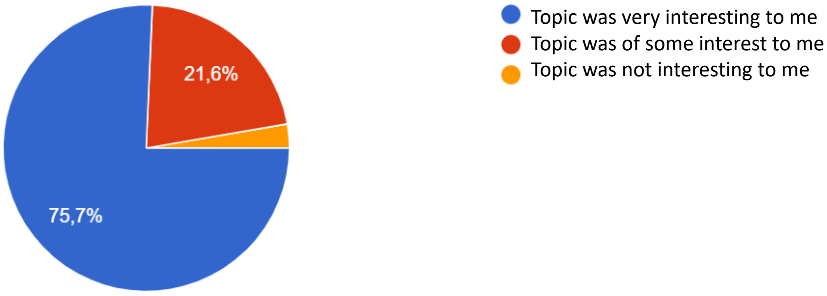

Figure 10. Question: Choose one alternative concerning the chosen topic (WPT).

Figure 11. Question: How much you think you learned due to this project?

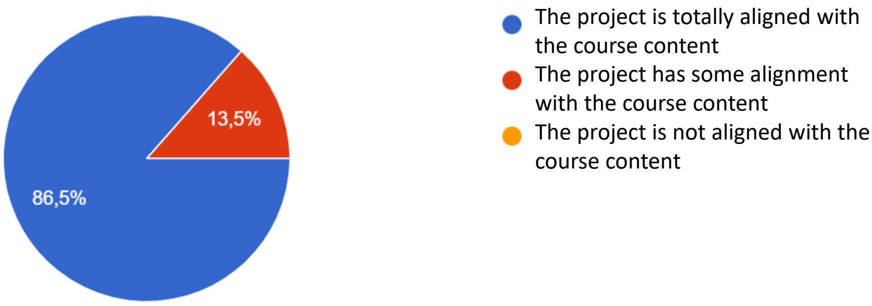

Figure 12. Question: According to you, is the project aligned with the course content?

References

Black, A. E., & Deci, E. L. (2000). The effects of instructors' autonomy support and students' autonomous motivation on learning organic chemistry: A self-determination theory perspective. *Science Education*, *84*(6), 740–756. https://doi.org/10.1002/1098-237X(200011)84:6<740::AID-SCE4>3.0.CO;2-3

Bou, E., Alarcon, E., & Gutierrez, J. (2012). *A Comparison of Analytical Models for Resonant Inductive Coupling Wireless Power Transfer*. 5.

Cossovich, R. (2020). *A PROJECT BASED LEARNING APPROACH TO ELECTROMAGNETISM*. 1786–1792. https://doi.org/10.21125/edulearn.2020.0581

Cutri, R., Roberto Marim, L., & Roberto Cardoso, J. (2022). Using project-based learning to teach electromagnetic and wave concepts. *The International Journal of Electrical Engineering & Education*, *59*(1), 20–32. https://doi.org/10.1177/0020720919828990

El Hage, F. S. (2022). Complete cycle of modeling and simulation for wireless power transfer using circuit theory, simple electronics, and open-source software. *Engineering Research Express*, *4*(4), 045026. https://doi.org/10.1088/2631-8695/aca37a

El Hage, F. S., Vieira, F. P. B., & Carareto, R. (2021). Deriving and validating an electrodynamic model of a voltage transformer from scratch. *European Journal of Physics*, *42*(3), 035207. https://doi.org/10.1088/1361-6404/abed9f

Halliday, D., Resnick, R., & Walker, J. (2014). *Halliday & Resnick Fundamentals of physics* (10th edition). Wiley.

Holubova, R. (n.d.). *Effective teaching methods—Project-based learning in physics*.

Khemkhaeng, T., Nutwong, S., Mujjalinvimut, E., Maiket, S., & Wiraphonsawan, N. (2022). Design of a Current Source Half-bridge Inverter Used in WPT System. *2022 19th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON)*, 1–5. https://doi.org/10.1109/ECTI-CON54298.2022.9795631

Kurs, A., Karalis, A., Moffatt, R., Joannopoulos, J. D., Fisher, P., & Soljačić, M. (2007). Wireless Power Transfer via Strongly Coupled Magnetic Resonances. *Science*, *317*(5834), 83–86. https://doi.org/10.1126/science.1143254

Rosenbaum, F. J., Vu, T. B., Vander Vorst, A., de Salles, A. A. A., Mao, Y., El-Khamy, S. E., Wiesbeck, W., Mukherji, K. C., Shapira, J., Yamashita, E., Shugerov, V., Malherbe, J. A. G., Gardiol, F. E., & Parini, C. G. (1990). Teaching electromagnetics around the world: A survey. *IEEE Transactions on Education*, *33*(1), 22–34. https://doi.org/10.1109/13.53624

Samanta, S., Rathore, A. K., & Thrimawithana, D. J. (2017). Analysis and Design of Current-Fed Half-Bridge (C)(LC)–(LC) Resonant Topology for Inductive Wireless Power Transfer Application. *IEEE Transactions on Industry Applications*, *53*(4), 3917–3926. https://doi.org/10.1109/TIA.2017.2681622

Seroglou, F., Koumaras, P., & Tselfes, V. (1998). History of Science and Instructional Design: The Case of Electromagnetism. *Science & Education*, *7*(3), 261–280. https://doi.org/10.1023/A:1008649319416

Proposal of Method for Risk Assessment of Failure in Undergraduate Final Project Report – UFPR (Undergraduate Thesis) when using Project-Based Learning

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Abstract

Project-Based Learning – PBL has been generally used in engineering education because it is expected to develop students' professional knowledge. PBL research and practices in engineering education are growing. Project management in engineering education is essential for preparing undergraduate thesis to solve practical problems in local companies. The authors conducted in-depth literature research to identify papers about the risk factors in preparing an undergraduate thesis and PBL application and found no specific study that addressed these three integrated subjects.

The study proposes a method to identify the risks of using the PBL method in preparing undergraduate theses by engineering students involving projects conducted in partnership with local companies.

A Case Study was conducted on applying PBL to support preparing an undergraduate thesis to solve practical problems in local companies within a specific region. The process was mapped out to identify the risks, and a relationship diagram was used to identify the categories of risks. A method to conduct undergraduate thesis projects based on project management principles is proposed.

As a result, the risks were identified, and the responses to the risks were defined. A method showing the steps to conduct the project and the examination criteria are presented. The conclusion is that implementing a response to risks and using the proposed method can optimize the resources and lead to a better-quality undergraduate thesis.

Future research directions for engineering education researchers are proposed to optimize project-based learning (PBL) undergraduate thesis. The study provides a method to be used by professors, students, and decision-makers to identify risk factors that can impact the preparation of undergraduate theses and a method to be followed to improve the quality of teaching in engineering education. The contribution is significant since it improves the quality of teaching in universities.

Keywords: Active Learning; Engineering Education; Project-Based Learning - PBL; Risk Assessment; Undergraduate Thesis

1 Introduction

Student-centered teaching methods using Project-based learning (PBL) have been widely used. Still, universities find it difficult to deal with unexpected issues during the implementation phase and often return to traditional teaching methods (Henderson, 2012). Therefore, it is essential to identify, describe, and deal with risk factors that directly impact PBLs and the preparation of an undergraduate thesis. It has been noticed that current literature on the use of PBL in engineering education has not addressed the risks of undergraduate thesis PBL failure, and even less attention has been paid to risk responses to ensure excellence in projects. The authors reviewed the literature to identify and list key risk factors when implementing PBL in engineering education. Awareness of these risks and how to respond to them can improve the chances of success when implementing PBL to enhance student learning and provide a sustainable teaching method at universities. The objective is to propose a method for risk assessment to identify the risks and responses to ensure a successful PBL undergraduate thesis conducted in collaboration with local companies. If risk factors are not identified, and proper responses are not provided, PBL undergraduate thesis project can lead to lower quality projects. This study assesses the risks and completes a gap in the literature by assessing the risk factors of using the

Project-Based Learning Method in preparing undergraduate theses by engineering students. The diversity of risk factors presented here highlights the complexity of using PBL in engineering education. To be addressed most of these risks require proper responses, and this need justifies this project. If risks are not identified and appropriately addressed, PBL projects can fail, and the students, professors, and partner organizations will not obtain the expected benefits. This paper is significant since it will help the development of skills and practice of professors and students and increase the quality of the PBL undergraduate thesis. It is noteworthy here that the study focuses on project-based learning involving companies. Successful PBLs, in this case, will significantly reduce business risks and achieve excellence in quality and organizational safety. None of the studies herein dealt with risk assessment and its impacts on PBL undergraduate thesis. The literature revealed that most previous studies addressed PBL and challenges without giving a method for preparing an undergraduate thesis using PBL.

The paper responds to the following research questions:

Research Question 1: What are the significant risk factors for using PBL in collaboration with local companies when preparing an undergraduate thesis?

Research Question 2: What are the responses to risks, and what method could professors and students use to manage a successful Undergraduate Thesis process?

Research Question 3: Is Project management in engineering education important in preparing undergraduate theses to solve practical problems in local companies?

This paper is divided into five sections: the first introduces the concepts of the study; the second describes PBL and its challenges; the risk assessment of PBL failure and the preparation of an undergraduate thesis; Section 3 describes the methodology of this work; section 4 results, and section 5 concludes.

2 Project-Based Learning

Previous significant studies about PBL Methodology and Challenges in its implementation and GFRP - Graduation Final Report Projects (Undergraduate Thesis) are presented in subsections 2.1, 2.2, and 2.3.

2.1 Design of PBL Method

Previous significant studies about PBL are presented herein. Moliner et al. (2019) developed a work that describes the experience of using PBL methodology in Materials Science courses conducted by four Spanish universities on different engineering degrees. The author analyzed and evaluated how the PBL was perceived by the students and lecturers who participated in the PBL process. Setiawan (2019) conducted a study focusing on implementing PBL, specifically on the opportunities and challenges. The students chose their topic, identified it, explained why, and solved it. Thevathayan (2018) presented an experience of evolving a hybrid-teaching process using the action research cycle plan-act-observe-reflect over three semesters. The main novelty of the approach was using projects with varying levels, which gave students an enjoyable and beneficial project experience. Marques (2018) proposed a formative monitoring method to help students be aware of their individual and team performance. The results indicated that PBL effectively enhanced the learning experience in the instructional scenario studied. Schneider (2020) used PBL to enhance student engagement, and Daun (2016) discussed the results from the long-term application of such a course design in a graduate setting. In addition, he indicated that project-based learning techniques foster different teaching goals in graduate and undergraduate settings. Du et al. (2013) developed a framework for change in educational culture by using a PBL methodology. This framework aims to inspire curriculum design for education and analyze the implementation of PBL in each cultural context.

Palmer and W. Hall (2011) presented a PBL offered in engineering PBL at Griffith University in Australia. The author observed that students enjoyed the experience, and the aspects needing improvement were listed and documented. García-Martín and E.Pérez (2017) presented a method to guide teachers using PBL principles and several instructional design processes. In particular, the process deals with defining a problem facing three fundamental issues in active learning, especially in PBL: Students' Motivation, Supporting Students' Work, and Autonomous Working. The authors focused on academic contexts where instructors are starting to use this method and students are not dealing with ill-structured projects. Du Bani et al. (2018) presented the main challenges facing PBL. The challenges included the type of projects, how to group students, how to proceed with planning, how to swap planning outputs among teams, and how to implement a Project.

2.2 Challenges and Risks in Project-Based Learning

Previous significant studies about the challenges of PBL are presented herein. The Henderson et al. (2012) survey mentioned that faculty are aware of student-centered teaching methods but find it challenging to deal with unexpected issues during the implementation phase. Thus, they often return to traditional teaching methods. Kjellberg et al. (2015) stated that implementing PBL is the holistic perspective of the project and that in most projects, the non-technical responsibilities are not clearly defined. The author says the complete infrastructure is not defined, probably due to a holistic project perspective and project management methods. These authors also stated that novice teams affected knowledge transfer and communication within extended teams, affecting group dynamics, commitment, and responsibilities. The authors highlighted that a lack of teacher teams leads to one teacher acting as both examiner and project manager. The authors also emphasized that the "two-hats" issue added to the teacher workload and created emotional stress due to the lack of tools and support and the constant brooding on addressing issues that appear. Beddoes et al. (2010) explained that challenges to the implementation and execution of PBL are both theoretical and practical. Theoretically, debates remain over the best approach to incorporate PBL and the performance necessary to benefit students. Some engineering educators argue that the maximum benefits of PBL will not be obtained unless it is implemented across the entire curriculum and all at once (Inelmen, 2003).

On the other hand, some authors argue that due to the significant differences between PBL and traditional methods, instructors should start with small-scale initiatives to incrementally familiarize themselves with PBL (Hansen, Cavers, & George, 2003). The changing roles of the teacher and the student are widely recognized as two of the most significant barriers to implementing PBL (Prince & Felder, 2006; Strobel, 2009). PBL can be difficult for faculty and students "because it challenges them to see learning and knowledge in new ways" and blurs boundaries (Savin-Baden, 2007, p. 24). For instance, students may be hostile to PBL because they are unaccustomed to the level of personal responsibility required and may experience conflicts with team members (Prince & Felder, 2006). Moreover, teachers often find it difficult to adjust to PBL (Prince & Felder, 2006; Thomas, 2000). Furthermore, institutional difficulties include resources, scalability, physical facilities, and management (Bielefeldt et al., 2009).

2.3 UFPR – Undergraduate Final Project Report (Undergraduate Thesis)

Lekhakul and Higgins (1994) stated that engineering design had become a critical element of the undergraduate engineering curriculum. The senior design course develops project management and oral and written communication skills and enables students to learn scheduling, team coordination and cooperation, parts ordering, and cost/performance trade-offs. Agricola et al. (2021) showed that our supervisors' in-the-moment decisions firmly focused on student learning. Supervisors often ask questions to empower students or to increase student comprehension. These supervising strategies seemed to fit students' needs, as the latter had positive insights when their control augmented or when they received stimuli to think for themselves.

Agricola (2018) et al. gathered qualitative and sixteen videotaped mentoring meetings coded in four diagnostic phases. The results were compared within and between mentors, showing that mentors asked several diagnostic questions, seldom articulated and shared their diagnoses explicitly with students, and mainly used interventions. We concluded that more support is needed for mentors who do not automatically use their diagnostic questions to formulate definitive diagnoses about students' research skills.

Bjerså et al. (2019) conducted thirteen interviews on experiences of bachelor's thesis examination. The analysis resulted in three categories: 1 - Beneficial; the examination session was seen as a positive learning experience, with students showing an interest in further studies. 2 – Demotivating and containing experiences of unfairness and unnecessary aspects. 3 - Improvement; suggestions were made based on the experiences of being present with beneficial and destructive elements at examination sessions. The authors concluded that students perceived the examination session as promoting learning, giving insight into scientific work, and as a forum with possibilities for improvement of their thesis. On the other hand, it could be destructive for relationships when fellow students act unfairly during the review, and the sessions must be prepared and practiced. To have a proper and fair assessment, better consensus, and standardized settings for the lecturers acting as examiners and supervisors.

Reynolds and Thompson (2011) stated that one of the best opportunities undergraduates must learn to write like a scientist is to write a thesis after participating in faculty-mentored undergraduate research. Dowd et al. (2019) studied Student Learning Dispositions and Multidimensional Profiles to Highlight Important Differences among Undergraduate STEM Honours Thesis Writers. The authors stated that various personal dimensions of students—particularly motivation, self-efficacy, and epistemic beliefs—can change in response to teaching, affect student learning, and be conceptualized as learning dispositions. Dowd et al. (2015) found that, although we cannot disentangle some gradual changes from specific interventions, students exhibited the strongest performance when they participated in a course with structured scaffolding and used assessment tools explicitly designed to enhance scientific reasoning in writing. Furthermore, less prepared students exhibited more positive changes. Wang (2011) studied an online management system for undergraduates' thesis (design), which is of great significance and great practical value for improving teaching management and teaching quality.

Stappenbelt (2017) studied action learning in undergraduate engineering thesis supervision. The author concluded that the action learning environment implemented had a measurable, significant positive effect on student academic performance, their ability to cope with the stresses associated with conducting a research thesis, the depth of learning, the development of autonomous learners, and student perception of the research thesis experience. Stappenbelt and Basu (2019) studied the student-supervisor-university expectation alignment in the undergraduate engineering thesis. The authors observed that alignment between student and university expectations regarding undergraduate thesis accountabilities in the present study was generally poor. The inconsistency between supervisor and university expectations was even more significant, with academic staff assuming most of the accountability for many essential thesis activities. The post-survey discussion pointed out that the driver for this behavior was mentor expectations that undergraduate thesis research would contribute to publications. Taking primary accountability for core thesis tasks away from the student, although improving the chances of successful research output, diminishes the ability to assess adequate academic performance accurately. The learning intended to result from the undergraduate thesis is devalued when research outcomes are prioritized over the research process.

Miller and Pessoa (2016) examined students' challenges in writing organized texts using effective thesis declarations and topic paragraphs by analyzing confrontational history articles written by multilingual students enrolled in an undergraduate history course. By identifying these challenges, the authors aimed to help teachers and students create a meta-language to mention these textual features of academic writing and thus improve the teaching and writing of academic writing. They call for explicit instruction to enhance students' organization of their ideas.

3 Methodology

The research used the keywords: Active Learning; Engineering Education; PBL; Risk Assessment, and Undergraduate Thesis. For selecting the publications of interest, they were searched by title, abstract, and keywords, and the focus was on the papers published in the last five years. The searched papers were reviewed by reading the abstract and introduction; those relevant to the research objectives were selected. The papers covering problem-based learning and not covering the Design of PBL, challenges/risk assessment of PBL failure, and undergraduate thesis were disregarded.

The study adopted the approach of building theory from Case Study Research (Eisenhardt, 1989), Yin (2014), and Hayes. (2022). It combined data from archives, interviews, and observations and focused on the application of PBL by a university in partnership with a company. A process map was constructed, and a list of risk factors in the researched literature was prepared. A quality management and planning tool named Relationship Digraph was used to cluster the risk factors into categories and establish the cause-and-effect relationship to the failure of PBL. A method was prepared based on traditional project management principles (PMBOK from PMI) and reviewed with students and professors. Students, professors, and professionals from a local university and its major partner company helped prepare the electronic process to maintain records. The responses to the risks were defined, and finally, the authors prepared the discussion of results and conclusion. The steps of the methodology are shown in Figure 1.

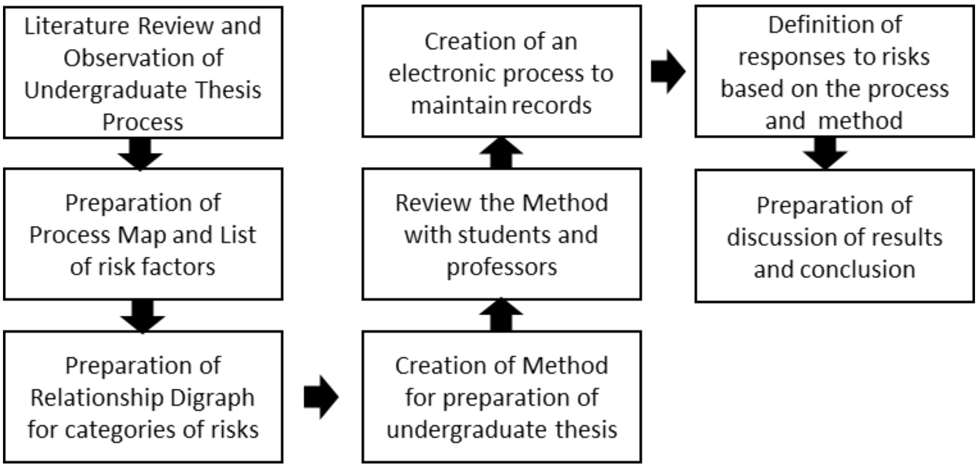

Figure 1. Methodology flowchart.

4 Results

This section shows the process map, the list of failure risk factors impacting PBL, and the proposed method. Following the sequence defined in the methodology, the process map and relationship digraph was used to prepare the list of risk factors organized by risk categories. The flowchart in Figure 2. shows the process map universities use in conjunction with partner companies in PBL projects and the risks presented in each step. The red letters represent the risk category: C: Cognitive Learning Failure, S: Social Learning Failure, and T: Theory and Practice Learning. The words in Blue represent the phases of the undergraduate thesis preparation, as shown in Figure 3.

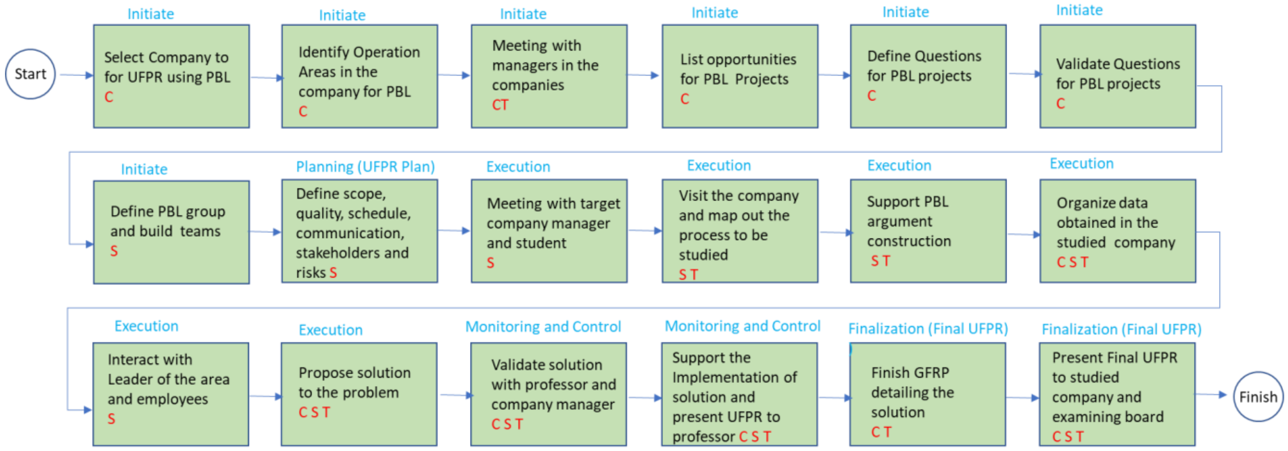

Figure 2. Structure in the conduction of Undergraduate Thesis PBL projects and risks.

The risk factors were clustered into categories to establish the cause-and-effect relationship to the failure of PBL. The affinity diagram was used to organize the risk factors within three learning principles and nine categories, as Xiangyun (2013) suggested. Risk factors leading to each risk category were identified based on the researched literature, as shown in Table 1.

Table 1. Risk Factors impacting PBL failure.

Type	Categories	Risks Identification	Risk Factors
C: Cognitive Learning Failure	CA: No Standardization of PBL Procedure	C1	Lack of procedure for the PBL process
		C2	Students and professors not appropriately trained on the PBL procedure
		C3	Lack of standard work for the execution of PBLs
	CB: PBL-specific requirements not defined accurately	C4	Poor explanation of expectations to students
		C5	Lack of background definition of the principle behind projects
		C6	No clear definition of the requirements
	CC: Wrong Choice of Project	C7	Project complexity incompatible with time and resources
		C8	The project is not related to discipline
		C9	Workload too heavy for the student
		C10	The low ability of students (slow learners)
S: Social Learning Failure	SA: Team Building practices not used	S1	The number of Students in the project is inadequate (too big or too small)
		S2	Project team members are not equally strong and interested
		S3	Assign students to teams rather than let them select the team themselves
	SB: PBL Professor not active in the project	S4	Professor does not give feedback on the project
		S5	Nonexistence of guidelines for team operation in the project
		S6	Students not encouraged by professors
	SC: Team lack of Motivation	S7	Some of the students were not active in the project
		S8	No focus on the project
		S9	Relationship professors and students are not good
		S10	Students and Professors lack patience and enthusiasm

T: Theory and Practice Learning Failure	TA: PBL Professor not prepared for the project	T1	Professor does not support knowledge base construction.
		T2	Professor does not support Argument base construction.
		T3	Lack of professor technical content knowledge and experience
		T4	Professor has no industrial skills.
	TB: No definition of PBL records organization	T5	Lack of definition for the project content organization
		T6	No definition of project report content
		T7	Problem-solving methods not defined
	TC: Students not prepared for the PBL	T8	Students are not familiar with the specific process theory behind PBL.
		T9	Students have no knowledge of Quality Tools for problem-solving
		T10	Students not trained on specific PBL process

The proposed method is shown in Figure 3. It starts with the initiation phase, where the GFRP Charter is prepared, and the identification of stakeholders is made.

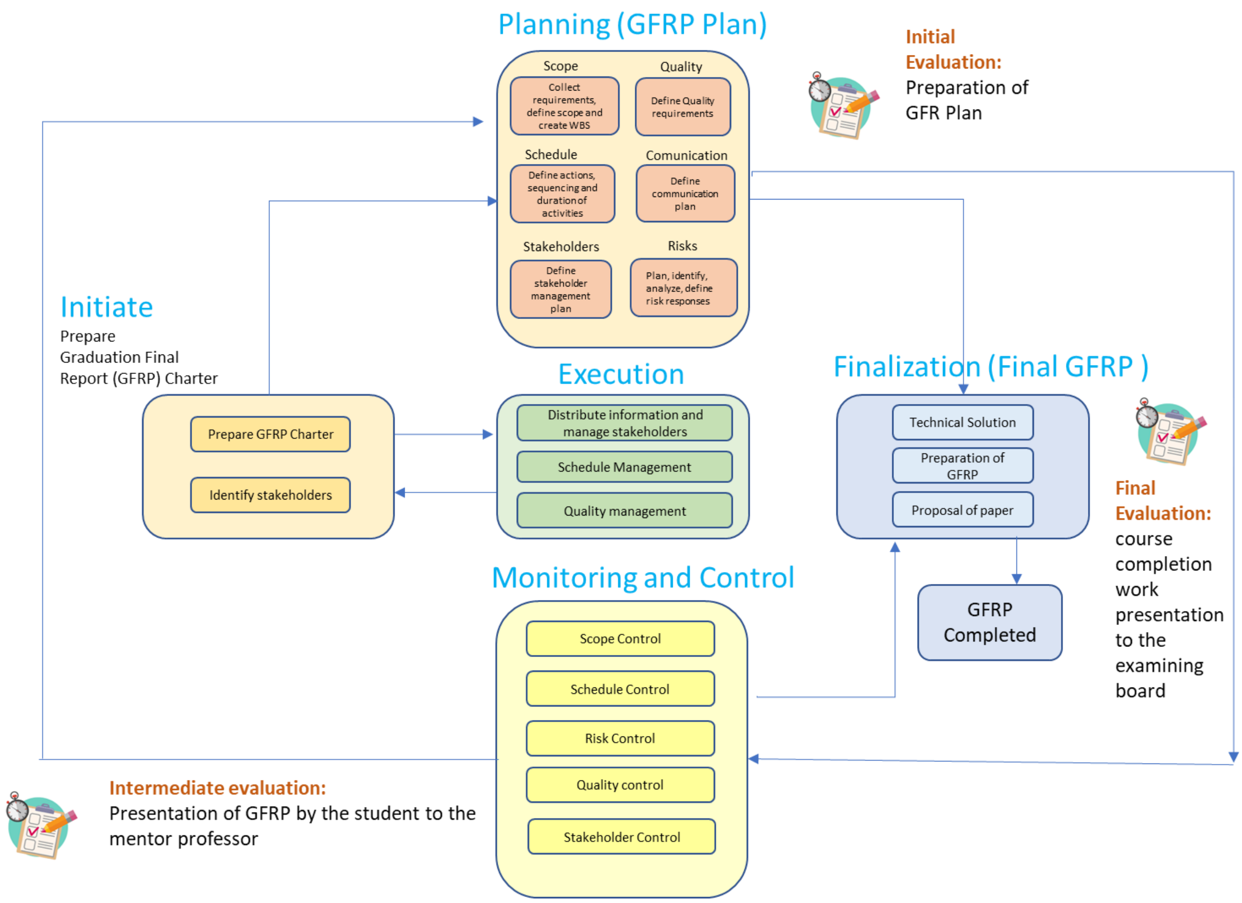

Figure 3. Method for Undergraduate thesis preparation.

In Phase 2, the Planning (GFRP Plan) is prepared, starting with the scope (collect requirements, define the scope, and create WBS), then the schedule preparation (definition of actions, sequencing, and duration of activities), the definition of stakeholders (define stakeholder management plan), Quality plan (Define Quality requirements), Communication plan (Define communication plan) and finally the Risks identification (Plan, identify, analyze, define risk responses). Phase 3 is the Execution Phase, with the collection and distribution of information, management stakeholders, and the management of Schedule and Quality. In Phase 4, monitoring and control happens, with the control of scope, risk, quality, schedule, and stakeholders. In Phase 5, the finalization of the GFRP, with the technical solution, preparation of the final GFRP, and paper. The Evaluation happens in three Steps. The first one is the Preparation of the GFR Plan; the second is the intermediate Evaluation with the presentation of GFRP by the student to the mentor professor and the Final Evaluation, with the course completion work (GFRP report) presentation to the examining board. The process must be documented in an electronic format, such as Google Form or another similar one.

5 Discussion of Results and Conclusion

As proposed in the introduction, the study presented the risk factors for using PBL in collaboration with local companies when preparing an undergraduate thesis, the responses to risks, and the method to be used by professors and students to manage undergraduate thesis. An in-depth analysis of current literature about the subject allowed the identification of risk factors in this process. This study shows evidence that PBL, in general, is subjected to many risks, some of which could compromise the teaching quality in universities.

An in-depth search for previous work dealing with risks in PBL was conducted and is described herein, and a process is proposed for risk assessment. This study is significant because understanding the risks in the undergraduate thesis PBL process can influence the decision of engineering school professors and university coordinators. Applying this innovative risk assessment method in the undergraduate thesis PBL process fills a gap in the literature since no previous work has dealt with this subject. The contribution is significant since risk assessment in the PBL process permits decision-makers to assign funds for critical activities that can impact universities' teaching quality. As initially stated, a process for preparing an undergraduate thesis is being proposed, allowing the optimization of resources and better quality in the result.

In response to the first question, "What are the significant risk factors for using PBL in collaboration with local companies when preparing an undergraduate thesis?" The significant risks were identified. Some of them in the category of cognitive learning are, for example, poor explanation of expectations to students, lack of background definition of principles behind projects, no clear definition of requirements, lack of procedure for the PBL process, and lack of standard work for the execution of PBLs. Regarding the social learning principle, impactful risk factors are, for example, assigning students to teams rather than letting them select the team themselves and students demotivated, not being able to be encouraged by professors. As regards the Technical Learning principle, impactful risk factors are, for example, lack of professor technical content knowledge and experience and lack of industrial skills.

In response to the second question, " What are the responses to risks, and what method could professors and students use to manage a successful Undergraduate Thesis process? Responses for the risks would be a better explanation of expectations to students, a proper background definition of principles behind projects, and a clear definition of requirements. An undergraduate thesis PBL procedure can standardize the PBL process, and the use of standard work for the execution of PBLs is very critical. Students should be allowed to select the team themselves and be encouraged by professors. The Professor supervising an undergraduate thesis should have technical content knowledge, experience, and industrial skills. The method to be used by professors and students is presented and can be used as guidance in preparing an undergraduate thesis.

In response to the third question, " Is Project management in engineering education important in preparing undergraduate thesis to solve practical problems in local companies?" An undergraduate thesis PBL robust process can standardize the execution of PBLs and lead to excellence in the preparation of undergraduate thesis.

The target of the study was to identify the critical risk factors that could affect PBL and propose an optimized process to ensure quality in PBLs. The implications are relevant since PBL process changes can substantially improve the result. By following the method, undergraduate thesis PBL failures can be prevented. The proposed method revealed some critical results, thus contributing to previous studies on the subject and may help overcome some of the challenges of professors, students, and other professionals looking for quality education. The study was conducted based on the experience and knowledge of professors and students. The present study is believed to augment the knowledge of engineering school professors, students, and coordinators and help use the proposed process. As the Introduction Section explains, several papers have been published addressing PBL use in different domains in recent years. However, no previous study could be found related to identifying risks in applying undergraduate thesis PBL. Notably, this paper proposes an optimized approach that could be used in any university or teaching organization.

This proposed method can guide the universities under the traditional teaching process to achieve quality improvement by following the proposed method. That helps to impact results, representing considerable teaching gains. The proposed method, enhanced by improved communication, enables any university to increase efficiency in education. This study shows evidence that the quality of the PBL process is affected by several factors, some of which can compromise the reliability of the teaching institution. In this regard, process analysis played a crucial role in understanding and implementing actions to improve it.

This study is significant because understanding the most impactful risk factors in the conduction of PBL can influence professors, students, and decision-makers in universities. As evidenced by the results, the modified method can help to optimize engineering teaching. As expected, the contribution is significant; it is believed that the present study will augment the knowledge of professors and students concerning using the PBL process to improve the quality and effectiveness of teaching. Scope for future research: This study opened some new research avenues. Opportunities for other case studies are abundant. They could be related to a broader application of risk analysis of undergraduate thesis PBL in specific cases, enhancing the current method and reducing the risk of failures.

6 References

Agricola, B. T., Prins, F. J., van der Schaaf, M. F., & van Tartwijk, J. (2021). Supervisor and student perspectives on undergraduate thesis supervision in higher education. Scandinavian Journal of Educational Research, 65(5), 877-897.

Agricola, B. T., Prins, F. J., van der Schaaf, M. F., & van Tartwijk, J. (2018). Teachers' diagnosis of students' research skills during the mentoring of the undergraduate thesis. Mentoring & Tutoring: Partnership in Learning, 26(5), 542-562.

Bani-Hani, E., A.Al Shalabi, F.Alkhatib, A.Eilaghi, and A.Sedaghat . 2018. "Factors Affecting the Team Formation and Work in Project-Based Learning (PBL) for Multidisciplinary Engineering Subjects." Journal of Problem-Based Learning in Higher Education 6 (2): 136–143.

Beddoes, K. D. , B. K.Jesiek, and M.Borrego . 2010. "Identifying Opportunities for Collaborations in International Engineering Education Research on Problem- and Project-Based Learning." Interdisciplinary Journal of Problem-Based Learning 4 (2): 7–34. doi: 10.7771/1541-5015.1142

Bielefeldt, A., Paterson, K., & Swan, C. (2009, February). The State of Project-Based Service Learning in Engineering Education. Report of the National Summit on Measuring the Impacts of Project-Based Service Learning on Engineering Education, Washington, DC.

Bjerså, K., Shams, K., & Fagevik Olsén, M. (2019). Physiotherapy undergraduate students' experiences of bachelor's thesis examination. European Journal of Physiotherapy, 21(1), 56-63.

Daun, M., Salmon, A., Weyer, T., Pohl, K., and Tenbergen, B. (2016). Project-based learning with examples from industry in university courses: An experience report from an undergraduate requirement engineering course. In 2016 IEEE 29th International Conference on Software Engineering Education and Training (CSEE&T), pages 184– 193.x

Dowd, J. E., Roy, C. P., Thompson Jr, R. J., & Reynolds, J. A. (2015). "On course" for supporting expanded participation and improving scientific reasoning in undergraduate thesis writing. Journal of Chemical Education, 92(1), 39-45.

Dowd, J. E., Thompson Jr, R. J., Schiff, L., Haas, K., Hohmann, C., Roy, C., ... & Reynolds, J. A. (2019). Student learning dispositions: Multidimensional profiles highlight important differences among undergraduate STEM honors thesis writers. CBE—Life Sciences Education, 18(2), ar28.

Du, X. , L.Su, and J.Liu . 2013. "Developing Sustainability Curricula Using the PBL Method in a Chinese Context." Journal of Cleaner Production 61: 80–88.

Eisenhardt, K. M. (1989). Building theories from case study research. Academy of management review, 14(4), 532-550.

Figueiredo, M. A. D., Ignacio, A. A. V., Guimarães, M. S. The initial process of the application of PBL in Industrial Engineering. PAEE

García-Martín, J. , and J. E.Pérez-Martínez . 2017. "Method to Guide the Design of Project-Based Learning Activities Based on Educational Theories." International Journal of Engineering Education 33 (3): 984–999.

Graaff, E., Kolmos, A., 2003. Characteristics of problem-based learning. International Journal of Engineering Education 19 (5), 657e662. Jucker, R., 2002. "Sustainability? Never heard of it!" e some basics we shouldn't ignore when engaging in education for sustainability. International Journal of Sustainability in Higher Education 3 (1), 8e18.

Hansen, D., Cavers, W., & George, G. H. (2003). Use of a Physical Linear Cascade to Teach Systems Processing. International Journal of Engineering Education, 19(5), 682-695.

Hayes, C. (2022). Methodology and Method in Case Study Research: Framing Research Design in Practice. In Conceptual Analyses of Curriculum Inquiry Methodologies (pp. 138-154). IGI Global.

Henderson, C., Dancy, M. and Niewiadomska-Bugaj, M. (2012), use of research-based instructional strategies in introductory physics: Where do faculty leave the innovation-decision process? Physical Review Special Topics-Physics Education Research, 8(2), 1-15.

Hyun, k. C, Min, S.,Choi, H., Park, J. Lee, In-Mo. Risk analysis using fault tree analysis (FTA) and Analytic Hierarchy Process (AHP) applicale to shield TBM tunnels. Tunnelling and Underground Space Technology., 49, 121-129.

Inelmen, E. (2003). Challenging the Administration to Implement Problem-Based Learning in

Kjellberg, K. , T.Adawi, and K.Brolin . 2015. "Challenges in Implementing PBL: Chalmers Formula Student as a Case." In Proceedings of the 43rd Annual SEFI.

Lekhakul, S., & Higgins, R. A. (1994). Senior design project: Undergraduate thesis. IEEE transactions on education, 37(2), 203-206.

Marques, M., Ochoa, S. F., Bastarrica, M. C., and Gutierrez, F. J. (2018). Enhancing the student learning experience in software engineering project courses. IEEE Transactions on Education, 61(1):63–73. ISSN 0018-9359

Miller, R. T., & Pessoa, S. (2016). Where's your thesis statement and what happened to your topic sentences? Identifying organizational challenges in undergraduate student argumentative writing. Tesol Journal, 7(4), 847-873.

Mls, K. and Otcenaskova, T. (2013) 'Analysis of complex decisional situations in companies with the support of AHP extension of Vroom-Yetton contingency process', IFAC Conference on Manufacturing Processing, Management and Control, June, Vol. 1, pp.549–554.

Moliner, L. , L.Cabedo, M.Royo, J.Gámez-Pérez, P.Lopez-Crespo, M.Segarra, and T.Guraya . 2019. "On the Perceptions of Students and Professors in Implementing an Inter-University Engineering PBL Experience." European Journal of Engineering Education 44 (5): 726–744.

Palmer, S. , and W.Hall . 2011. "An Evaluation of a Project-Based Learning Initiative in Engineering Education." European Journal of Engineering Education 36 (4): 357–365.

Requies, J. M. , I.Agirre, V. L.Barrio, and M.Graells . 2018. "Evolution of Project-Based Learning in Small Groups in Environmental Engineering Courses." Journal of Technology and Science Education 8 (1): 45–62.

Reynolds, J. A., & Thompson Jr, R. J. (2011). Want to improve undergraduate thesis writing? Engage students and their faculty readers in scientific peer review. CBE—Life Sciences Education, 10(2), 209-215.

Schneider, B., Krajcik, J., Lavonen, J., Geller, M. J., & Salmela-Aro, K. (2020). Learning science – The value of crafting engagement in science environments. Yale University Press

Setiawan, A. W. 2019. "Implementation of Project-Based Learning in Biomedical Engineering Course in ITB: Opportunities and Challenges." Proceedings of IFMBE Proceedings 68/1: 847–850.

Stappenbelt, B. (2017). Action learning in undergraduate engineering thesis supervision.

Stappenbelt, B., & Basu, A. (2019). Student-supervisor-university expectation alignment in the undergraduate engineering thesis.

Strobel, J., & van Barneveld, A. (2009). When is PBL More Effective? A Meta-synthesis of Meta-Analyses Comparing PBL to Conventional Classrooms. The Interdisciplinary Journal of Problem-based Learning, 3(1), 44-58.

Thevathayan, C. (2018). Evolving project-based learning to suit diverse student cohorts. In Proceedings of the 22nd International Conference on Evaluation and Assessment in Software Engineering 2018, pages 133--138. ACM.

Thomas, J. W. (2000). A Review of Research on Project-Based Learning. Retrieved June 7, 2009, from www.bobpearlman.org/BestPractices/PBL_Research.pdf

Wang, H. (2011, May). The design and implementation of an online management system for undergraduates' thesis (project). In 2011 International Conference on E-Business and E-Government (ICEE) (pp. 1-4). IEEE.

Yin, R. K. (2014). Case Study Research Design and Methods (5th ed.). Thousand Oaks, CA: Sage.

Xiangyun D., Liya S., Jingling L. (2013). Developing sustainability curricula using the PBL method in a Chinese context. Journal of Cleaner Production. Volume 61, 15 December 2013, Pages 80-88.

Teamwork and peer assessment in the construction of prototypes and ventures in the subjects of Introduction to Systems and Computing Engineering and Introduction to Industrial Engineering supported by the project-based learning approach

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Abstract

This paper describes teaching and learning strategies designed under a project-based learning approach PBL. The learning activities that will be carried out by students from the Introduction to Systems and Computing Engineering and Introduction to Industrial Engineering subjects at the National University of Colombia for the formulation and execution of projects are detailed. The first strategy is called ¡Build a prototype of your solution! It is implemented in the Introduction to Systems and Computing Engineering subject, and a second strategy is called Structure your business project! The latter is implemented in the Introduction to Industrial Engineering subject. The PBL principles on which these strategies are built are teamwork, in which ethical, communication, and time management factors are integrated, and peer assessment. The learning strategies include four workshops. The first three workshops are developed by each team, and the last workshop is carried out between students of the two subjects for peer assessment. The first workshop includes activities to identify the local context problem, propose possible alternative solutions, and formulate the project. The second workshop includes selecting the solution alternative and recognizing methodologies to implement the solution. The third workshop integrates implementing the solution alternative. The fourth workshop includes listening to the peer´s assessment, adjusting the prototype or project according to the peer's assessment, and presenting the most appropriate alternative solution. Each team has three weeks between the execution of each workshop to carry out the activities for delivering their final project in week 14 of the semester. Regarding peer assessment, the students use rubrics to assess teamwork and the prototype or project. The evaluation products are a written report of the project, an oral presentation, a poster, and a video presented in an academic forum.

Keywords: Project-based learning; Engineering Education; Computer and systems engineering; Industrial engineering.

1 Introduction

These teaching and learning strategies are based on the three dimensions addressed by the principles of project-based learning. The first dimension is the problem. In this research, the problem is framed in the local context of the department of Cundinamarca and the Bogotá D.C. in Colombia. The idea is that the problem motivates the student, arouses their interest, and facilitates the formulation of the research question. In this sense, the knowledge and previous experience of the students regarding the problems of their environment are relevant. The second dimension is the content, typical of the discipline, which includes interdisciplinarity. It is related to the knowledge of the fundamentals of engineering, natural sciences, and human sciences, including the limits and traditional methods related to the subject. Through the implementation of teaching and learning strategies in the subjects of Introduction to Systems Engineering and Introduction to Industrial Engineering, which are part of the first semester of engineering in higher education, the previous knowledge acquired in secondary education is the main support for the formulation of the problem. This dimension also includes exemplary practice, which implies that the student achieves the learning result in an integral way, achieving a deep understanding of the formulation and solution of the problem.

Finally, the third dimension is team learning, which indicates that most learning processes take place in groups and teams. However, these processes are still student-centered and self-directed, according to the Danish concept of participant-directed learning, where it addresses the ownership of the learning process and the formulation of the problem. This implicitly develops personal competencies for managing group cooperation processes. (Kolmos, Fink, & Krogh, 2006).

The teaching and learning strategies in this research focus on teamwork and peer assessment. Teamwork, TBL for its acronym in English (Team-based learning), focuses on the integration of communication, time management, and ethics in engineering. TBL combines large- and small-group learning in a subject setting with 50-60 students, which is considered large. (Haidt, Kubitz, & McCormack, 2014). A great deal of effort is put into the appropriate design of the learning activities. Some of the elements that are considered in this design are the number of students that will make up the team, the collective decision-making that each activity implies, time management for interaction between members, methods, and techniques and tools to promote communication between team members that facilitate decision making. Learning in teamwork and the usefulness of that learning must be visible to both the students and the professor (Haidt, Kubitz, & McCormack, 2014).

To make team-based learning and its application visible in the context of a central theme aimed at formulating and solving specific problems in the local context, the contribution of the solution is identified in relation to the Sustainable Development Goals. The actions to be carried out by the students are also defined, including the generation of ideas for possible solutions, their presentation, reflection, discussion and decision making based on professional ethics. Similarly, a fundamental factor for a successful learning process in TBL is communication. It is necessary to guarantee frequent verbal and written interaction between the students during the execution of the defined actions Another determining factor for the success of the implementation of PBL, is time management, which becomes relevant during the execution of each of the actions in the execution of the project. In the context of engineering, the formulation of problems and projects and their evaluation by peers implies a process of feedback and exchange of knowledge. This constitutes a mechanism that promotes responsible action in students to evaluate the value of their contributions to the team effort. In the same sense, peer review and evaluation contribute to the efficient and accurate assessment of student's teamwork skills. (De Graff & Saunders-Smits, 2007).

The design of the courses Introduction to Systems and Computing Engineering and Introduction to Industrial Engineering using the PBL approach is in line with two mission principles of the Universidad Nacional de Colombia, which are: "To study and analyze national problems and propose, with independence, relevant formulations and solutions" and "to train professionals and researchers on a scientific, ethical and humanistic basis, equipping them with a critical conscience, so that they may act responsibly in the face of the demands and trends of the contemporary world and creatively lead processes of change" (Presidencia de la República de Colombia, 1993). There are two teaching and learning strategies that have been developed within the framework of project-based learning for the two subjects. The first strategy is called "Build the prototype of your solution" and the second is called "Structure your business project", for which its scope and composition are described.

2 Scope of teaching and learning strategies

For each teaching and learning strategy, its general perspective, pedagogical objectives, intended learning outcomes and intervention design are described, with emphasis on the activities defined for each phase. For each of the workshops their temporal sequence during the academic period is indicated.

2.1 Project "Build the prototype of your solution"

The general perspective of this learning strategy incorporates the PBL principles of problem solving, disciplinary content and teamwork, focusing on teamwork and peer assessment. This strategy is developed from an enlistment phase and the development phase of four workshops, and it seeks to answer the following research question: How does teamwork and peer assessment in the project-based learning approach improve the construction of solution prototypes to the problems formulated by the students?

The learning intended outcomes defined by the curriculum committee are "Motivate the student and place him in the best way in the social practices of the disciplines that make up engineering and his specialty in systems and computing, facilitate the understanding of the concepts developed and the historical evolution of Engineering and specifically of Systems and Computing Engineering and provide elements to develop oral and written communication skills, teamwork, autonomous learning, leadership and creativity”.

Within the framework of the proposed strategy, the intended learning outcomes are; the students are able to define the fundamental concepts related to Systems and Computing Engineering and their application in solving problems local context, evaluate trends in science, technology and innovation of the fourth industrial revolution, in the short, medium and long term and their application in solving local and global problems, apply the problem-based learning approach and the scientific method for the formulation and solution of real Engineering problems in the local context, identifying its contribution within the framework of the Sustainable Development Goals - SDGs and contemplating intercultural or international approaches. In addition, to apply the fundamental concepts related to the areas of Information Systems, Information Sciences, Computing, Software Engineering, and Intelligent Systems in the solution of real problems of the local context and communicate effectively and adequately to achieve their objectives based on knowledge, aptitudes, and intercultural abilities.

The design of the Intervention in the subject of Introduction to Systems Engineering and Computing contemplates two phases, these are the Enrollment phase and the execution of the workshops phase.

- The enlistment phase focuses on the conceptualization and foundation of Systems and Computing Engineering through teams made up of three students, this will allow the students to get to know each other before forming the teams for the construction of the prototype. This activity includes the reading of documents previously selected by the professor, writing a reflection report and analysis of the concepts and foundations, the presentation of the concepts by student teams, the delivery of a video for internal socialization of topics addressed by the students. members of each team, and the socialization of the themes by a member of each team in the group.
- The workshop execution phase includes a first activity for the formation of teamwork with several six members for the realization of the prototype. The TBL is carried out to meet the expected results of each workshop. The description of each workshop is shown in Table 1.

Table 1. Workshop.

Workshop	Description
A	this includes the definition of the problem of the local context, this implies the description of the problem situation and the formulation of the problem through the research question. Also, the statement of the objectives, general and specific, the justification of the problem, description of the referential framework in which students include the following frameworks: theoretical, conceptual, background, historical, demographic, legal, ethical in the local context and the identification and proposal of possible alternative solutions.
B	this corresponds to the study and design of the solution alternatives, this includes the following activities: Requirements analysis, selection of the solution alternative, and selection of the methodology to implement the solution, design of the solution prototype, requirements for implementation of the solution prototype, specification of criteria for testing and verification of the solution prototype.
C	this includes the implementation of the solution alternative in coherence with the previously established requirements, methodological design in which students specify the type of research, population, sample, hypothesis, variables, information collection and the analysis plan for the evaluation of the implementation of the prototype and delivery of the prototype for peer assessment.
D	this integrates the peer assessment, presentation of the results of the peer assessment, and issuance of recommendations. As well as the adjustment to the prototype according to the recommendations, the preparation of the final project report, the production of the video and the presentation of the prototype in the academic forum. The evaluation of the learning process of the students in the enrollment phase is carried out through the following products: Test of knowledge about the application of basic concepts of Systems Engineering and Computing in the solution of problems in the real context, written document of the conceptual maps that reflect the reading of the documents, oral presentation about the application of the basic concepts in the solution of problems of Systems Engineering and Computing.

Regarding the learning process assessment, it’s carried out through the following products:

- Written Report on the progress of the prototype
- Follow-up report on teamwork.
- oral presentation of progress in the construction of the prototype.

The evaluation is carried out through the following products:

- Report of the result of the evaluation by peers delivered by each team with respect to the evaluated team.
- Academic poster.
- Final written report of the prototype.
- video presentation of the prototype, in the same way this form includes the presentation of the prototype in the academic forum.

Table 2. Sequence in time of the execution of synchronous learning activities.

Synchronous / Face-to-face at the University	Phase/Workshop/week
Formation of Teams, oral presentation regarding the application of fundamental concepts of Systems Engineering and Computing in real problems, appropriation of concepts about Learning Based on Problems or Projects.	1/ Enlistment / 1 -2
Definition of the Problem of the local context, this implies the description of the problem situation and the formulation of the problem through the research question, declaration of the objectives, general and specific, justification of the Problem.	2 / A / 3-5
Requirements Analysis.	2 / B / 7-8

Methodological Design in which students specify the type of research, population, sample, hypothesis, variables, data collection, and the analysis plan for evaluating the implementation of the prototype. Delivery of the prototype for peer review.	2 / C / 10-11
The presentation of the results of the evaluation by peers of the evaluation teams and the Active Listening of the results of the evaluation by peers and recommendations by the teams that were the object of the assessment.	2 / D / 12-13
Presentation of the prototype in the academic forum.	2 / D / 14

Table 3. Sequence in time of the execution of asynchronous learning activities.

Asynchronous / Virtual or Face-to-face	**Phase/Workshop/week**
Reading documents, fundamental concepts of Systems Engineering and Computing applied to problem solving, preparation of a written report.	1/ Enlistment 1 -2
Preparation of the Referential Framework.	2 / A / 6
Selection of the solution alternative, and selection of the methodology to implement the solution. Design of the Solution prototype, requirements for the Implementation of the Solution prototype, specification of criteria for the test and verification of the solution prototype. Implementation of the Solution Alternative in coherence with the previously established requirements.	2 / B / 9
Peer assessment, adjustment to the prototype according to the recommendations, preparation of the final project report, production of the video.	2 / D / 12-13
External by expert assessment.	2 /D/14

2.2 Project "Structure your Business Project"

The general perspective of this second strategy also incorporates the PBL principles previously stated, team-based learning is focused on the structuring of the business or entrepreneurial project of the students. The structuring of their business project is carried out in groups made up of five students.

In the enlistment phase, each group proposes ideas for products that can be manufactured and therefore must comply with the fact that the production process does not generate any risk for the students. , that the materials used as inputs are cheap and that the production process has several steps to transform the inputs into the final product. Subsequently, once the ideas of each group have been heard, one product per group is selected with the endorsement of the professor. Once the product has been selected by group, students must structure their business by simulating the creation of a company. In the business project, the theory seen in face-to-face sessions during class hours must be applied, that is, they must present the company's mission or reason for being, the five-year corporate vision, business values and an analysis of the business environment of the company, both micro and macro, that is, they must establish their suppliers, their customers, their distributors, and their competitors. In turn, they must analyze the social, legal, environmental, and economic context of the company according to the sector to which it belongs.

They must also design the organization chart with which the company will work and define what position each of the members of the group will occupy and it must be a consensus among them. On the other hand, students must present the production process and set a sale price for the product considering the inputs and the market. Finally, they present their business model using the Canvas. (Osterwalder & Pigneur, 2009). Regarding the learning results of the students, by implementing this strategy it is desired that the students be able to: apply the fundamental concepts about the modeling of a business process developed throughout the semester and simulate the four main functions of the administrative process: planning, organization, direction, and control in the field of the created company. In turn, with this strategy they apply the project-based learning approach in the national and international business context, integrating knowledge with the attitudes and skills of the members of the work team. The products delivered by each work team of the Introduction to Industrial Engineering subject are the same as those of the Introduction to Systems and Computing Engineering subject, namely: Report on the result of peer assessment delivered by each team regarding the evaluated team, academic poster, final written report of the prototype, video presentation of the prototype and presentation of the final project in class and in the academic forum.

3 Team-based learning and peer assessment

The workshop D take place during week 12-13, the peer assessment process is carried out by eighteen work teams from the two groups G1 and G2 of the Introduction to Systems and Computing Engineering course – ICSE – , these team are differentiated by colors. Also, the peer assessment is carried out by eleven team of Group G1 of the Introduction to Industrial Engineering subject – IIE – these teams are differentiated by numbers. The assignment of teams to assess and be assessed is carried out as observed in Table 4.

Table 4. Assignment of teams for peer assessment.

Name of the Teams that will be assessment in ISCE / Information about the prototype.	**Number of the IIE teams that will be advisors and carry out the assessment.**	**Number/ Teams that will be assessment in IIE.**	**ISCE teams that will be advisors and carry out the assessment**
Purple – Web application for the optimization of the ID process at the University.	← 1,2	1. Inlac - Innovative Dairy Industry of Caquetá Colombia	← Mayan blue – Green
Pink – Design of an Information repository of disciplinary content of Systems Engineering and Computing.	←3,4	2. Gru's Goodies - Jams for people with diabetes	← Black – Blue
Navy water blue – Web page to provide information on free courses offered by the student branch.	←5,6	3. Hatis – plants and decorations	← Sky-blue – Brown
Fuchsia – Web page about the importance of eating healthy foods in students.	← 7,8	4. Terra – 100% natural organic fertilizers	← Pea green – White
Green – Dynamic web page to make visible the Systems and Computing Engineering curriculum.	←9,10	5. Nova Design - Lithograph custom designs	← Red – Midnight Blue
Sky-blue – Precalculus educational software to support learning in young people in grades 10 and 11 of the IPARM School.	← 1,2	6. KaffaLAB - High quality coffee of various presentations	← Orange – Yellow
Midnight Blue – Web page to make visible the importance of good coexistence as a key factor to overcome selfishness in Systems and Industrial Engineering students.	←3,4	7. Makweb - Websites and digital marketing	← Purple – HeatTech
Brown – Web page for time management in engineering students.	←5,6	8. Sollaris - clean energy and everyone's reach	← Pink – Navy water blue
White – Design of a digital platform for the promotion of sexual health in young people.	←7,8	9. Basten – organic wet cat food	← Fuchsia – Amber
Yellow – Vertical Farms in Ciudad Bolívar Bogotá D.C.	←9,10	10. Cotton Cycle - Textile production with recycled cotton	← White – Fuchsia
HeatTech – Mobile Application to contribute to the improvement of Engineering students and professors.	←1,2		

Amber – Application to connect Social Workers with Engineering students to deal with situations related to academic pressure.	←3,4		
Mayan blue – Social Interaction App for Safety in Public Transport	← 5,6		
Black – Website to raise awareness about good nutrition in the academic community.	← 7,8		
Blue – App to report abuses of gender-based violence	← 9,10		
Pea green - Web page for the development of good recycling habits among university students from the Jaime Benítez Tobón Foundation.	← 1,2		
Red – Web for awareness and reporting of gender-based violence	← 3,4		
Orange – App for responsible management of students' financial resources	← 6,7		

4 Rubric used to assess the prototype and the venture.

The rubric used to assess the prototype built by the students in the Introduction to Systems and Computing Engineering subject and the rubric used to assess the entrepreneurship proposed by the students in the Introduction to Industrial Engineering subject are described in Tables 5 and 6.

Table 5. Rubric for the peer assessment of the prototype.

Content Rating	**Budding performance [1]**	**Acceptable performance [2]**	**Performance satisfying [3]**	**Optimal performance [4]**
Title of the project	Does not include the Project Title.	It includes the Title of the Project, it does not give an account of what is going to be done when, how and where or function of the company.	It includes the Title of the project specifying what it is going to do, when, how and where, or the function of the company, but it has some errors.	It includes the Title of the project specifying what is going to be done, when, how and where, or the function of the company correctly.
Definition of the problem	It does not specify the problem situation or includes a reflection on the problem to be addressed.	Specifies the problem situation superficially, does not delve into the causes and effects.	It specifies the problem situation, defines the problem, and delves into the causes, but superficially in its effects.	Specifies the problem situation, defines the problem delving into the causes and effects.
Project Rationale	It does not include the Project Rationale.	Includes a Project Rationale, but it is not complete, precise, or coherent enough.	Includes the Project Rationale with specifications.	It includes the Project Rationale with specifications and reflects on the social effect.
Project Objectives	It does not present and does not correctly state the objectives of the project.	It presents the objectives; however, they are not well stated and there is no evidence of inconsistency in their sequence.	It presents the objectives, they are well stated, but it presents a coherence in its sequence.	It presents the objectives; they are well stated and there is evidence of coherence in their sequence.
Referential Framework	It does not include the referential framework that addresses the frameworks: theoretical, background, conceptual, ethical, demographic, and legal.	Includes a brief referential framework with the frameworks: theoretical, background, conceptual, ethical, demographic, and legal.	It includes the reference framework with the frameworks: theoretical, background, conceptual, ethical, demographic, and legal, addressing fundamental aspects for the execution of the project.	It includes the reference framework with the frameworks: theoretical, background, conceptual, ethical, demographic, and legal, addressing fundamental aspects and the reflection and discussion of the aspects.
Analysis of Solution Alternatives and Selection of the Optimal Alternative	Does not Present Alternative Solutions, does not formulate Possibilities to respond to the problem and Does not Select the optimal solution.	Presents Solution Alternatives, formulates Possibilities, but does not select the optimal solution.	Presents Solution Alternatives, formulates Possibilities, selects the optimal solution, without including the evaluation and execution of	Presents Solution Alternatives, formulates Possibilities, selects the optimal solution, and includes evaluation and execution of

			the prototype.	the prototype.
Methodological design	It does not reflect on the methodology to be used. It does not formulate the hypothesis, nor does it define the variables. It does not include methods, techniques, and procedures for the development of the project.	The work includes a partial reflection about the methodology, but does not formulate the hypothesis, nor define the variables. It does not include methods, techniques, and procedures for the development of the project.	Reflect on the methodology and formulate the hypothesis, define the variables. However, it does not include methods, techniques, and procedures for the development of the project.	Reflect on the methodology and formulate the hypothesis, define the variables, include methods, techniques, and procedures for the development of the project.
Innovative Solution.	The solution will have no effect on the initial situation.	The solution will have a low positive effect on the initial situation.	The solution will have a medium positive effect compared to the initial situation.	The solution will have a high and positive effect compared to the initial situation.

The rubric for the evaluation of the Entrepreneurship is built from the Model Canvas (Osterwalder & Pigneur, 2009) and in the lean startup metrics applied to Dave McClure's conversion funnel (Croll & Yokovitz, 2013).

Table 6. Rubric for the peer assessment of the venture.

Content Rating	**Budding performance [1]**	**Acceptable performance [2]**	**Performance satisfying [3]**	**Optimal performance [4]**
Company Name	It does not include the fully identified company name.	It includes the business name of the company but does not account for the productive sector.	It includes the business name of the company specifying the productive sector.	It includes the reason for the company specifying the productive sector and the name is innovative.
Problem	The relevance of the problem is not evident, it does not have interviews on the problem, it does not include systematic ordered information that indicates the social importance of solving the problem.	The relevance of the problem is not evident, it does not have interviews about the problem. However, it includes systematic orderly information that indicates the social importance of solving the problem.	The relevance of the problem is evidenced, it has interviews about the problem, it includes information about the social importance of solving the problem. But it is partially ordered and systematic.	The relevance of the problem is evidenced, it has interviews on the problem, it includes information about the social importance of solving the problem and it is totally ordered and systematic.
Solution	It does not include the characteristics of the product or service that the company is going to offer.	It partially includes the characteristics of the product or service.	It includes the characteristics of the product or service in detail.	It includes the characteristics of the product or service in detail and giving an account of the contribution to society and the customers to whom the product or service is directed.
Unique Value Proposition	Does not include potential customers' perceptions of the product or service (interview analysis).	Partially includes the perceptions of potential customers about the product or service, specifies or designs interviews or surveys. However, the analysis of the information is not evident.	Partially includes the perceptions of potential customers about the product or service, specifies or designs interviews or surveys. It includes the partial analysis of the information.	It includes in detail the perceptions of potential customers about the product or service, specifies or designs interviews or surveys, and includes partial analysis of the information.
customer segment	It does not identify potential customers, the customer segment to which the product or service is directed, and the feasibility of paying for the product.	It partially identifies potential customers but does not indicate the customer segment to which the product or service is directed and does not include the feasibility of paying for the product.	Identifies and details characteristics of potential customers, indicates the customer segment to which the product or service is directed. However, it does not include the feasibility of paying for the product.	Identifies and details characteristics of potential customers, indicates the customer segment to which the product or service is directed, and includes the feasibility of paying for the product.
Channels	It does not include the evaluation of the channels	It includes the evaluation of the channels to take the	It includes the evaluation of the channels to take the	It includes the evaluation of the channels to take the product to the

	to bring the product to customers.	product to the clients, however, it does not specify the potential clients by channel.	product to the clients, specifies the potential clients by channel, selects the optimal one.	clients, specifies the potential clients by channel, selects the optimal one. It includes coefficients of variability, opening indexes, inflation indexes.
Competitive advantage	It does not reflect on what makes it unique compared to other competitors, it does not identify possible patents regarding its product, it does not identify barriers to entry.	It partially reflects on what makes it unique compared to other competitors, it does not identify possible patents regarding its product, it does not identify barriers to entry.	Reflect on what makes it unique compared to other competitors, identify possible patents regarding your product, and do not identify barriers to entry.	Reflect on what makes it unique compared to other competitors, identify possible patents regarding your product and identify barriers to entry.
Income Streams	It does not include aspects to measure the income stream, it does not identify the value of the customer's life cycle.	It partially includes aspects to measure the revenue stream, however, it does not identify the value of the customer's life cycle.	It includes detailed aspects to measure the income stream, identifies the value of the customer's life cycle.	It includes detailed aspects to measure the flow of income, identifies the value of the customer's life cycle and additionally includes information about the average income of customers, conversion rate, purchase frequency.
Cost Structure	It does not assess how much the company costs, it does not establish whether the business is profitable or not.	It partially assesses how much the company cost; however, it does not specify if the business is profitable or not.	Evaluate in detail how much the business cost, however, and specify whether the business is profitable or not.	Evaluate in detail how much the business costs, however, and specify whether the business is profitable by pointing out fixed, variable, customer acquisition, technical support, and marketing costs.

5 Adjusting the prototypes and projects regarding the peers assessment

The types of projects according to the technology solution carried out by the student teams of the Introduction to Systems Engineering and Computing course are web pages 28%, software specific purpose 28%, mobile applications 17%, mobile applications, web platforms, digital platform, databases, and urban vertical farms correspond to 6% for each one. Regarding the contribution of the solutions formulated with the SDGs, 99% of the prototypes are aimed at contributing to Sustainable Development Goal 4. Quality Education. Of these, 33% focus on prototypes for the improvement of: secondary education in exact sciences, higher education in Engineering and computer science, the application of learning methods and communication between academic advisors and students, among others. 44% focus on improving education related to good health and well-being SDG 3. 17% on improving education in relation to gender equality and equity SDG 5, prevention of gender-based violence and finally 6% in the improvement of education related to decent work and economic growth. On the other hand, 6% focuses on urban vertical farms that seek to contribute to the sustainable development objectives SDG 2 Zero Hunger, SDG 3 Good Health, and Well-being.

The written documents with the information corresponding to the formulation of the problem and the alternative solution or prototype are delivered to each of the teams formed in the subject of Introduction to Industrial Engineering for evaluation. In turn, the industrial engineering groups deliver the projects to the Systems Engineering groups for peer assessment. Subsequently, the evaluation teams present the results of the peer assessment to the evaluated teams, the latter will make the adjustments for their final delivery.

The strategies are carried out during the first semester of 2023. The results will be analysed and presented in the second semester of 2023 before the curricular committees of the undergraduate programs.

6 Conclusions

The development of a project throughout the semester allows applying the theory taught in class, working in teams generating ideas and sharing knowledge and providing students with a global vision of systems engineering or industrial engineering and its areas as a profession.

Ethical, communication and time management factors make up the peer assessment of team-based learning.

The assessment of the learning of the disciplinary content of the subject through peer assessment facilitates the improvement of the prototype and the business project, as well as the generation of knowledge, in the students.

The follow-up carried out by the students within the framework of team-based learning of each activity carried out during the workshops makes it possible to recognize the contributions and significant contributions of each member of the team.

Timely feedback on progress regarding the prototype or project design ensures that students achieve the intended learning outcomes.

References

De Graff, E., & Saunders-Smits, G. N. (2007). PEER Assessment and PEER review to support teamwork in engineering. Conferencia: 6º Coloquio Global ASEE sobre Educación en Ingeniería En: Estambul, Turquía. doi:10.1109/WIRELESSVITAE.2011.5940815

Haidt, P., Kubitz, K., & McCormack, W. T. (2014). Analysis of the team-based learning literature TBL comes of age. Journal on Excellence in College Teaching, 25(3&4), 303-304. Obtenido de https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4643940/

Kolmos, A., Fink, F. K., & Krogh, L. (. (2006). The Aalborg PBL model – Progress, Diversity and Challenges. Aalborg, Denmark: Aalborg University Press. Obtenido de https://samples.pubhub.dk/9788773079119.pdf

Osterwalder, A., & Pigneur, Y. (2009). Business Model Generation. Obtenido de https://www.camarabaq.org.co/wp-content/uploads/2020/11/Generacion-de-Modelos-de-Negocio-2010.en_.es_.pdf

Presidencia de la República de Colombia. (06 de 28 de 1993). Decreto de Ley 1210 DE 1993. Obtenido de Sistema de Información Normativa Jurisprudencial y de Conceptos -Universidad Nacional de Colombia: http://www.legal.unal.edu.co/rlunal/home/doc.jsp?d_i=34144

Skills development with a focus on self-awareness and self-management: the power is in the student's hand

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Abstract

Self-awareness and self-leadership are complex terms to define because they involve strengths, weaknesses, beliefs, interests, motivations, and emotions. This paper shows a practice to help students develop and improve soft skills using a process based on Deming's Plan-Do-Check-Act (PDCA) continuous quality improvement model, implemented in engineering programs at the Unifei - Itabira, conducted by two professors. In addition, it describes the end-to-end implementation strategy starting from self-awareness, planning, execution, assessment, and sustainment of the improved process in a step-by-step approach composed of three phases, in which students were fully active as self-managers of their own development. Phase 1. Diagnosis: self-awareness of the soft skills students most frequently practise and the other ones they needed to develop. Phase 2. Selection of Soft Skills: students elaborated an action plan to improve three soft skills they prioritised. And Phase 3: the analysis of the action plan results generated and replanning, if necessary. This experience was carried out in 2021, and 237 students participated in it. Phase 1 was experienced by 100% of the students. In this phase, the following percentage of students reported these soft skills as the most frequently practised: Ethics and Humanism (98%); Collaboration (98%); Multidisciplinary (86%); Update on new technologies (72%), and Resilience (67%). At phase 2, experienced by 188 students, Oral and Written Communication was prioritised by 46% of students, followed by Organization (41%), Entrepreneurship (36%) and Creativity (33%) and Innovation (32%). Phase 3, in which the students needed to complete the PDCA cycle, was accomplished by 180 students. At the end of this experience, 90% reported that they perceived improvement in their prioritised soft skills. The study also showed that through self-awareness and self-leadership students can develop their soft skills in an autonomous way.

Keywords: Soft Skills; Engineering Education; Self-awareness; Self-management; Self-leadership.

1 Introduction

Global imperatives have led engineering education institutions to rethink their teaching methods, seeking to provide more teaching-learning experiences so that the student becomes more active in the process. In Brazil, the new Curriculum Guidelines for Engineering published in 2019 are an example of experience at the federal level for universities to be more effective in proposing practical experiences, articulated with external agents in professional environments so that the graduate is a critical subject , proactive and engaged in solving business, social and technological problems.

It is in this context that teachers and managers of these institutions have sought new active teaching practices to escape traditional teaching methods. In these models, the teacher is the only holder of knowledge and the student is a true “student” devoid of the light of knowledge that only the teacher has. This format is considered archaic and does not adapt to the different learning formats that Generation Z students present.

The changes that contemporary society has experienced call for new teaching-learning models, which opens up space for the use of active learning strategies, which favours the development of skills and transversal skills needed to face current challenges. However, it is believed that for students to be really active in their self-development process, they need to develop the meta-competences of self-awareness and self-leadership.

This paper shows a practice to help students develop and improve soft skills using a process based on Deming's Plan-Do-Check-Act (PDCA) continuous quality improvement model (Werkema, 1995), implemented in engineering courses at the Unifei - Itabira, conducted by two professors. In addition, it describes the end-to-end implementation strategy starting from self-awareness, planning, execution, assessment, and sustainment of the improved process in a step-by-step approach composed of three phases, in which students were fully active. This experience was carried out in 2021, and 237 students participated.

2 The importance of self-awareness and self-leadership to achieve the development of soft skills

One of the biggest challenges in engineering education is to provide learning experiences considering the human dimension of the workplace. In this field, these challenges cannot be addressed with technical knowledge alone. The interdisciplinary nature of engineering and these complex challenges require engineers with diverse experiences, knowledge, perspectives, skills, etc. (Joslyn & Hynes, 2016).

For this reason, the so-called soft skills have an important role in the training of engineers (Souza & Campos, 2019). These skills are considered transversal competences that are beyond technical subjects but are also related to professional practice (Lima, Mesquita, Rocha, & Rabelo 2017). In the literature, the soft skills receive different names such as “generic”, “transferable”, “dynamic” (Halász & Michel, 2011). Thus, soft skills are more generic skills in the world of work, with attitudes and actions that help the individual to apply her/his knowledge in different situations, essential for professional life (Lima, Mesquita, Rocha, & Rabelo 2017).

In the literature, it can be found a list of several soft skills engineers must have, such as communication, creativity, innovation, adaptability, organisation, problem solving, resilience, proactivity, teamwork among others (Souza & Campos, 2019). In this context, engineering students must be supported, not only in the development of their technical competences, but also in the improvement of their soft skills.

In the view of this, it can be said that self-awareness is a meta-competency that must be acquired before developing the other soft skills (Urich, 2018). In other words, first students must be aware of their inner dimensions in order to develop their other soft skills. In this sense, it is considered that someone can only reach their full potential when this person knows her/himself enough to make the best decisions in view of her/his personal goals. In this circumstance, self awareness is a state of self-directed attention and represents the extent to which one has identified and can articulate the personal values, professional values, and assumptions regarding professional roles and responsibilities that inform her/his professional identity (Cech, 2014).

In addition to that, it is important to mention that self-leadership complements self-awareness, in the pursuit of soft skills development. Self-leadership is a comprehensive self-influence process capturing how individuals motivate themselves to complete work that is naturally motivating or work that must be done but is not naturally motivating (Stewart, Courtright & Manz, 2019). Bryant (2012) observes that self-leaders have developed a sense of self-awareness and efficacy and demonstrate the ability to influence a leader's communication, emotions, and behaviour.

Considering self-awareness and self-leadership as fundamental concepts of this discussion, as research suggests, the development of any skill is best facilitated by giving students practice and not by simply talking about or demonstrating what to do (Woods et al, 2000). In this context, the instructor's role is different from the traditional teaching process where professors are the experts responsible for showing the right way of behaving (Mansetto, 2018). Instead, the instructor is primarily a coach, encouraging the students to achieve the target attitudes and skills and providing constructive feedback on their efforts (Woods et al, 2000).

In this sense, Woods et al. (2000) suggests basic activities to promote soft skill development. First of all, the instructor must identify the skills students have to develop, include them in the course syllabus and (if department faculty agree) the university curricular planning, and communicate their importance to the students. In the context of engineering education, the instructor can select these skills from official documents that are determined by federal institutions that regulate the educational systems in her/his country. In Brasil, the National Curriculum Guidelines for the Engineering Programs published by the Ministry of Education is an important reference. In this step, the instructor can also use research to identify the target skills, and share the research with the students. Lima, Mesquita, Rocha, & Rabelo (2017) present a set of soft skills that is demanded in the context of engineering education.

Besides sharing the source of chosen soft skills, Woods et al (2000) suggest that the instructor must make explicit the implicit behaviours associated with successful application of the soft skills. It is important because in some cases, the meaning of the soft skills is not known by students. Even when the meaning is familiar, sometimes, the soft skills is an abstract concept and asks for a proper interpretation and exemplification so that the student has clear references of which behaviours encompass a certain soft skill.

In addition, the instructor must provide extensive practice in the application of the soft skills, using carefully structured activities, and provide prompt constructive feedback on the students' efforts using evidence-based targets. With the objective to induce self-leadership, the instructor must encourage monitoring among students. As Woods et al (2000) suggest, monitoring is the metacognitive process of keeping track of, regulating, and controlling a mental process, considering past, present and planned mental actions. Furthermore, reflection must be stimulated as well, which is the metacognitive process of thinking about past actions trying to learn from mistakes and unsuccessful events. Yet, Woods et al (2000) recommend the instructors to grade the process, not just the product, using a standard assessment and feedback form as a way of stimulating students in their continuous learning.

The presented constructs presented in this session can be organised in a mental map (Figure 1) that summarises the soft skill development strategy proposed in this paper.

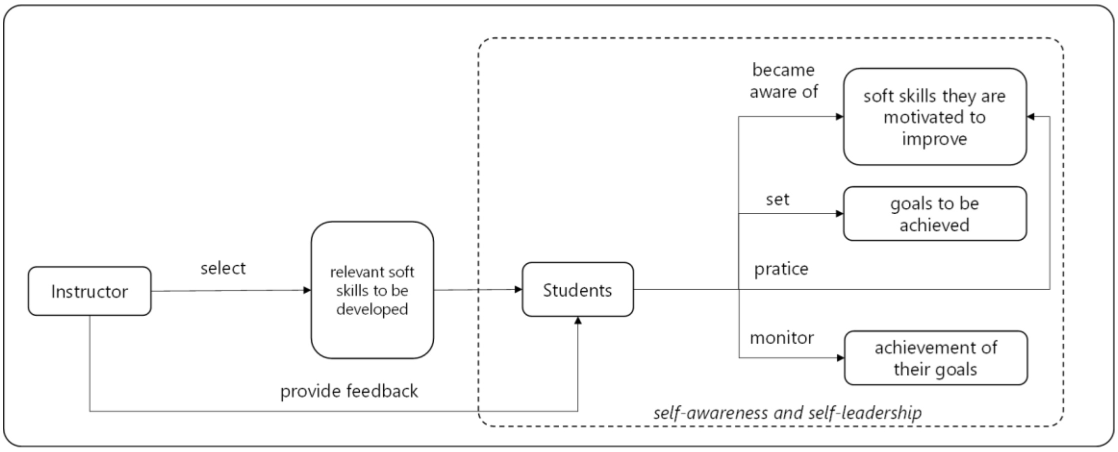

Figure 1. Mental map for soft skill development strategy based on self-awareness and self-leadership.

In this model, the instructor organises information and the environment to induce students to have their own opportunities to manage their improvement. The students must play the central role of the process while the instructor only moderates the situation so that her/his part is only a support.

3 Methodology

This experience of developing soft skills for engineering students was carried out at the Federal University of Itajubá (UNIFEI - Itabira campus), in the second half of 2021. This practice was based on Deming's Plan-Do-Check-Act (PDCA) continuous quality improvement model (Werkema, 1995), conducted by two professors.

The first step of the experience was to present to the students the relevance that soft skills have to engineers. Students were introduced to 12 soft skills required in the National Student Performance Examination (ENADE), as expected in the egress profile of the engineer programs offered at UNIFEI - Itabira campus. These are those soft skills and their impact in professional performance:

1 - oral and written communication: it is critical for effective communication in professional and personal settings, enabling students to convey their ideas clearly and persuasively.

2 - innovation: it enables students to think outside the box, generate new ideas, and develop innovative solutions to real-world problems

3- creativity: enable students to think and to execute different forms of action to improve results and generate value.

4- resilience: equips students with the mental and emotional strength to overcome challenges, bounce back from failures, and persist in their pursuit of goals.

5- entrepreneurship: a mindset that encourages students to think creatively, identify opportunities, and take risks, which are essential qualities for innovation and success in today's dynamic and competitive world.

6- collaboration: it fosters teamwork, diversity of ideas, and the ability to work effectively with others, which are essential skills in today's interconnected and globalised world.

7- multidisciplinarity: it allows students to broaden their horizons and integrate knowledge from different fields, enabling them to solve complex problems with a holistic perspective.

8-organisation: it helps students manage their time, resources, and tasks efficiently, enabling them to be more productive and achieve their goals effectively.

9- updated on new technology: it provides students with opportunities to enhance their digital literacy, adapt to technological advancements, and stay relevant in the rapidly changing job market.

10- proactivity: it means to act before being asked and before being forced by circumstances.

11-criticality to solve problems: it encourages questioning variables, processes and information in search of the fundamental causes of problems and opportunities for improvement.

12- ethics and humanism: it means to act correctly from an ethical, moral and human point of view.

Professors explained the "Development of Soft Skills of Engineering Student" experience to students as a proposal to help students to improve their personal skills. The Deming's Plan-Do-Check-Act (PDCA) continuous quality improvement model (Werkema, 1995) was presented to students and they were invited to use this management model as a tool of self-awareness and self-leadership.

After this introduction, the method was applied in 5 stages, with information collected via electronic forms:

1- Students answered a self-assessment questionnaire about the frequency of practice of the 12 soft skills presented;

2- The overall results of the self-assessment were presented, when the less frequent soft skills were identified in the context of the students;

3- From the reflections on the self-assessment, the students were invited to outline an improvement plan for the development of 3 prioritised soft skills;

4- The professors analysed the plans presented by the students and gave feedback to the students, evaluating the quality of the analyses and proposed actions to improve the soft skills.
5- The professors applied a questionnaire in order to get to know the status of execution of the improvement plan students outlined in stage 3. It was possible to know the percentage of actions executed and the perception of improvement students felt up to that moment. In case of not noticing improvement, students were invited to reschedule new actions to improve their soft skills.

Table 1. Milestones of the experience.

Date	Milestones	PDCA Phase
August 2022	First day of class: presentation of soft skill development experience	1-Plan - 1.1 problem identification - choice of soft skills to be developed
	Presentation of soft skills and self-assessment	1-Plan - 1.1 problem identification - prioritisation of soft skills to be developed
September 2022	Improvement plan subscription	1-Plan - 1.2 phenomenon analysis - self-assessment of soft skills to be developed; 1.3 process analysis: identification of causes of non-developed soft skills; 1.4 improvement plan: proposition of efficient actions to improve soft skills
	Execution of Improvement plan	2-Do - execution of Improvement plan
	Improvement plan feedback	3 - Check - check of execution of improvement plans and perceived results of soft skills improvement 4- Act - definition of new actions in case of non-perceived improvement and standardisation of actions that produced good results
November 2022	Status of improvement plan execution	
December 2022	End of experience and final feedback	- - -

The sample calculation was based on the work of Paiva (2021) and Ganga (2012). The sample was calculated using a tool shown in figure 2.

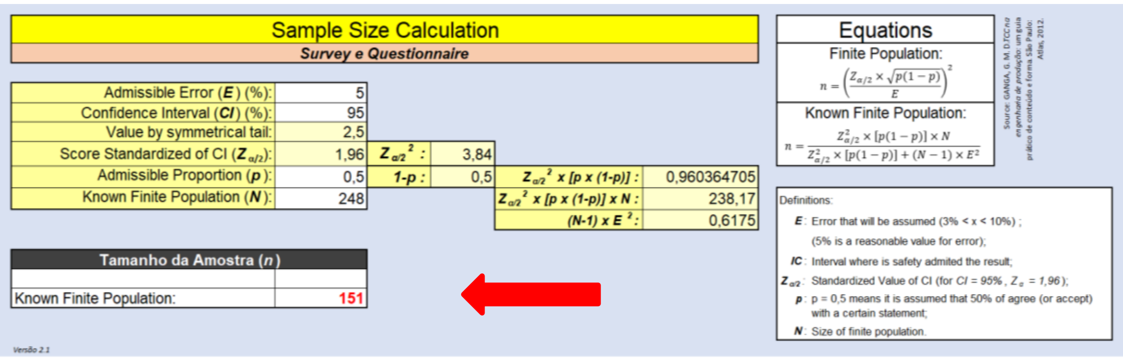

Figure 2. Sample Size Calculation Tool.

where N: Known Finite Population (248); Confidence Interval: 95%; Z=1,96 and Admissible error (E): %5. The result showed that this study needed 151 students to be accomplished.

4 Data Analysis

This experience was carried out in 2021, and 237 students participated. The data analysis was carried out in three phases as follows.

4.1. Phase 1: It was experienced by 100% of the students. In this phase it was possible to see the percentage of students that frequently practise each soft skill analysed, as presented in Figure 3.

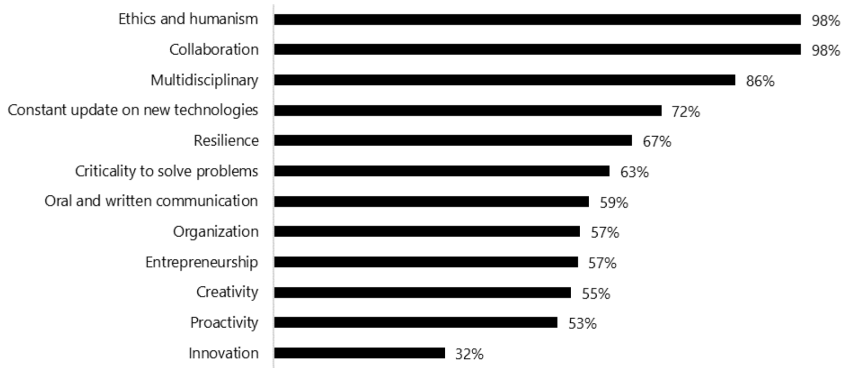

Figure 3. Percentage of students that frequently practise the analysed soft skills.

4.2. Phase 2: It was experienced by 188 students. In this phase students prioritised the soft skills they wanted to prioritise the development. Oral and Written Communication, Organization, Entrepreneurship and Creativity and Innovation were the most chosen ones. The figure 4 shows the soft skills organised by the percentage of choice among students.

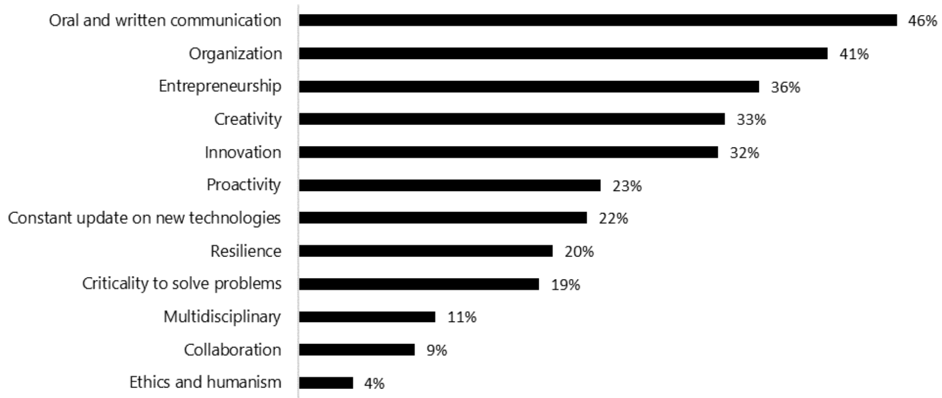

Figure 4. Percentage of students that prioritized each soft skills in phase 2.

After prioritizing the soft skills they wanted to develop, students outlined an improvement plan for the development of the 3 prioritized soft skills. The plans are elaborated using the reference 5W2H (Figure 5)

What?	Who?	Where?	Why?	When?	How?	How m
Participation in Project XYZ	Talk to a professor	Send an e-mail	Because the project can help me to improve my soft skill "Organization"	Until July 1th	I can attend all the meetings until the end of the project	Once a week

Figure 5. Action Plan based on 5W2H.

The professors analysed the plans presented by the students and gave feedback to the students, evaluating the quality of the analyses and proposed actions to improve the soft skills. 21% of the plans were considered excellent with a high standard description of the analysis and action propositions. 41% of plans were considered great, but presented improvement opportunities. They presented sufficient descriptions of analysis but were a little superficial when they proposed the actions to be executed. 35% of plans were considered good, but with several improvement opportunities. 3% of plans were considered insufficient with poor analysis and inadequate description of actions to be executed.

At the feedback about the improvement plan, the professors suggested some materials to help students in the development of the soft skills. In Table 2, there are some examples.

Table 2. Content suggested to help the development the soft skills.

Soft Skills	Suggestions	Soft Skills	Suggestions
Oral and Written Communication	Podcast: "Óh Quem Talk"	Entrepreneurship	Instagram: @sebrae
Organisation	Podcast: "Organize sem Frescura"	Creativity and Innovation	Instagram: @murilogun

4.3. Phase 3: In this phase, which the students needed to complete the PDCA cycle, 180 students participated. They had to answer a questionnaire about the status of action plan completion and about their perception of improvement of their prioritised soft skills. At this point, students reported that 34% of the improvement plan were concluded while 66% were in progress. Nevertheless, 90% of the students reported that they perceived improvement in their prioritised soft skills, as shown in Figure 6.

It is important to mention that students executed their plans from September to November. They had only 3 months to execute their improvement plan. Yet, when asked about the soft skills they did not perceive improvement, they reported that it happened in the cases they did not execute the tasks planned.

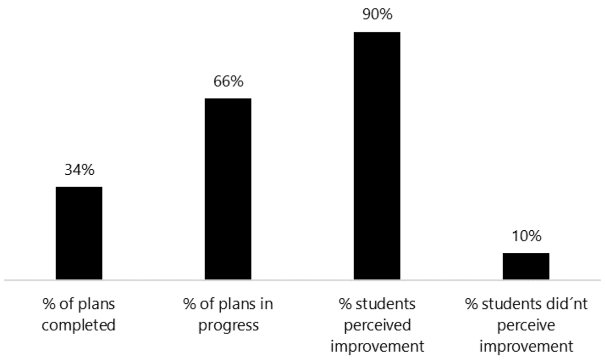

Figure 6. Results of phase 3 (completion of plans and perception of improvement).

Analysing the data presented, it is possible to affirm that students had the opportunity to practise their self-awareness and their self-leadership to develop their soft skills in an autonomous way. Even with a low rate of completion of the plans, students perceived improvements of their soft skills. They were invited to participate in a process that does not end in this experience, but will follow them in their professional life.

5 Conclusion

In conclusion, when soft skills development is subsidised by self-awareness and self-leadership, students are empowered to take control of their own learning journey. As a consequence, students are prepared for success in the modern world. In this sense, this experience demonstrated Woods et al (2000) assertion that the development of any skill is best facilitated by giving students practise.

In phase 1, it was possible to recognize the most frequently practised skills of the students. It was important to know the soft skills students report to be more acquainted with (ethics and humanism, collaboration, multidisciplinary, update on new technologies and resilience) and the other ones they have more difficult to perform (communication, organisation, entrepreneurship, creativity, proactivity and innovation). This is an important piece of information that can direct specific other learning experiences in order to give an extra incentive to specific skills.

In phase 2 reinforce the previews argument, once students prioritised the development of the least practised skills. In this case, it is possible to affirm that students practised their self-awareness and were active to self-leader their development. It is a relevant dimension of this experience because the students were responsible to identify their improvement opportunities, they investigated the causes of bad performance, they studied the better ways of achieving better results and wrote their improvement plans acting like real self-leaders.

Phase 3 represents the accomplishment of this experience because with 34% of completion of the improvement plans, 90% students reported perception of soft skills improvement. Considering this data, it is possible to affirm that this experience reached its goal of ensuring the power to be in the students' hand. Students can be taught to be self-leaders and the PDCA model was an efficient way to do this job, because it is intuitive and easy to execute. The assessment of the improvement in the soft skills presents a challenge for professors. Unlike traditional subject-based evaluations, measuring improvement in these skills requires a more holistic approach. One effective method is to integrate them into the curriculum, creating opportunities for students to apply these skills in practical situations. By incorporating group projects, debates, presentations, and real-world scenarios, professors can gauge students' growth in areas like teamwork, effective communication, and adaptability.

In conclusion, the skills development approach presented in this paper integrated different soft skills and empowered students to become lifelong learners who are well-prepared for the challenges and opportunities of the future. By putting the power in the hands of the students, it was possible to equip them with the skills necessary to thrive in the rapidly evolving world and make meaningful contributions to their communities and beyond.

Nevertheless, it is important to consider that this approach can be improved in several ways. First, a semester duration is short to execute a complete process of self-development. The majority of students would need extra time to properly fulfil their plans. Yet, the results of this experience are limited to some aspects such as students' motivation and mental health. Some students could not have enough self-discipline to go through this process and could demand extra help that professors did not notice. For these aspects, other extended opportunities could be offered considering these and other limitations.

As a field of research, this experience has a vast number of aspects that can be investigated in the future. So, it will be possible to explore other aspects that were not covered in this paper.

6 References

Agranonik, M., & Hirakata, V. N. (2011). Cálculo de tamanho de amostra: proporções. Clinical and Biomedical Research, 31(3). https://seer.ufrgs.br/index.php/hcpa/article/view/23574

Cech, E. A. (2014) Culture of disengagement in engineering education? Sci. Technol. Human Values 39, 42–72.

Daud, Y. M. (2020). Self-leadership and its application to today's leader-A review of literature. Strateg J Bus Change Manag, 8(1), 1-11.

Eurich, T., (2018) What Self-Awareness Really Is (and How to Cultivate It), Harvard Business Review, 4..

Ganga, , G. M. D. TCC na engenharia de produção: um guia prático de conteúdo e forma. São Paulo: Atlas, 2012.

Halász, G., & Michel, A. (2011). Key competences in Europe: interpretation, policy formulation and implementation. European Journal of Education, 46(6), 289-306. http://dx.doi.org/10.1111/j.1465-3435.2011.01491.x.

Joslyn, C.H., & Hynes, M.M. (2016). Measuring Changes in Self-awareness and Social-awareness of Engineering Students' Engaging in Human-Centered Design.

Lima, R. M., Mesquita, D., Rocha, C. & Rabelo, M. (2017). Defining the Industrial and Engineering Management Professional Profile: a longitudinal study based on job offers. Production. 27(spe), e20162299. http://prod.org.br/doi/10.1590/0103-6513.229916

Masetto, M. T. (2018). Metodologias ativas no ensino superior: Para além da sua aplicação, quando fazem a diferença na formação de profissionais? Revista E-Curriculum, 16(3), 650. https://doi.org/10.23925/1809-3876.2018v16i3p650-667

Paiva, E. J. de. Sample Size Calculation Tool. 2021.

Souza, A. S., & Campos, L. B. P. (2019). Habilidades transversais de engenheiros em formação: o papel de projetos de extensão. Research, Society and Development, 8(4), 32.

Stewart, G. L., Courtright, S. H., & Manz, C. C. (2019). Self-leadership: A paradoxical core of organizational behavior. Annual Review of Organizational Psychology and Organizational Behavior, 6, 47-67.

Werkema, C. (1995). As ferramentas da qualidade no gerenciamento de processos. 6. ed. Belo Horizonte, MG: Editora de Desenvolvimento Gerencial.

Woods, Donald & Felder, Richard & Rugarcia, Armando & Stice, James. (2000). The future of engineering education III. Developing critical skills. Chemical Engineering Education. 34.

Is it possible to form an engineer for the 21st century without considering the social sciences and humanities in their education?

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Abstract

In a world dominated by technology, which is advancing at a speed that in some cases seems impossible to follow, it is extremely important to understand, or at least study, the impact of technologies on society. Since engineers are the link between technology and society, they need to know the dimensions of the technologies they develop or apply in terms of human welfare, public policy, social change, and environmental impact. To know or test the potential impact of projects in the future, it is necessary to go beyond the technological and conceptual knowledge that characterises traditional engineering. To understand society's relationship to technologies and their impacts, it is necessary to draw on areas that have traditionally been distant or not considered relevant in engineering education. For the education of an engineer who will work in the 21st century, the convergence of social sciences and humanities with engineering education seems extremely important, not to say necessary. Today's society no longer accepts an engineer with purely technical training and performance. The engineer is expected, in addition to his technical and conceptual knowledge of engineering, to consider his work in its entirety and to be aware of the positive and negative impacts that his projects may cause. In this context, this article reflects on the importance of taking into account the social sciences and the humanities, attributing to them their importance in the formation of a complete engineer in today's world.

Keywords: Engineering Education; Social Sciences in Engineering Education; Humanities in Engineering Education; Competences in Engineering.

1 Introduction

Human relationships are present at any stage of an engineer's career and the ability to relate can facilitate their career development and be decisive for their professional success. However, there are even more important issues that are related to the social and environmental impacts, positive or negative, that engineering projects cause in the short, medium and long term and some of these impacts, especially the social ones, require considerations or analyses that go beyond the edges of scientific theories and technical concepts.

About Engineering, it is possible to affirm that it has always been noted for solving and finding solutions to complex problems of different natures and objectives and, especially in the current times, there are constant challenges that go beyond technical solutions or, at least, that appropriate technical solutions are developed and applied to specific environments or scenarios, taking into account the real needs of the society that will use technology, if there are people able to deal with technology and this technology has the potential to leverage the development of a given society (Tharakan, 2019). However, to develop appropriate technologies and go beyond strictly technical solutions, it is necessary to develop empathy for people and understand a society, a task that can be greatly facilitated with the approximation of the Social Sciences and Humanities (SSH).

Jablokow (2007) states that it takes more than engineering to be a good engineer. It is necessary to recognize, know how to deal with and consider differences and diversities, whether those behavioral of the people of a team or cultural of those who will be impacted by engineering. It is also important to know the evolution of technology and its impacts so that new and better technologies are developed.

When considering the performance of the engineer beyond the practices related to companies, there is no doubt that many engineers have a perspective of the social influence of their work and their responsibility in society. Thereis a kind of social contract that everyone signs that leads people to prevent harm to society. Engineers, as part of society, have the same (or greater) responsibility, but with their own knowledge and expertise that allows them to assume a unique role (Stieb, 2007).

The traditional education in Engineering already contemplates some Humanities, it is true, such as Administration, Economics or Law, through disciplines throughout the courses. More recently, much has been highlighted the importance of interpersonal relationships for the engineer that along with other skills are part of the so-called *soft skills*. These soft skills, however, have been treated to some extent as something secondary in the training of the engineer, because Engineering is very associated with developing strictly technical projects to solve problems or meet demands that come to engineers and these focus on applying the concepts and classical technical knowledge necessary of Engineering. Not always an engineer has the opportunity or even is asked to make a reflection of the social and environmental impacts that a project will have in the long run.

This way of developing Engineering finds roots in the education of engineers when they were in training in educational institutions that met, especially throughout the twentieth century, the demands of a labor market based on the Fordist-Taylorist model that required engineers with technical and specialized training, without the need for perceptions of the implications and consequences of their actions. The scenario begins to change still in the twentieth century, with the emergence of Toyotism, which began to require multitasking professionals focused on quality and adapted to consumer demands and, towards the end of this century, along with the effects of globalization the labor market begins to be changed drastically, going from a job market to a scenario of job scarcity and uncertainties. Educational institutions, then, which have spent almost a century training engineers to be employed, now must think about how to train engineers who will need to find space in a much more competitive market and that requires training beyond the technical, (Ludwig, 2018).

There has always been a very clear distance between Engineering and the Human Sciences, which tend to awaken a need for reflection on the issues that affect the human being. This distance is due to a certain prejudice of representatives of both areas, but an approximation between Engineering and SSH, especially in Engineering education, becomes extremely important, not to say necessary, for Engineering to be a protagonist and to lead transformations aiming at a better world and with more quality of life for all. The inclusion of SSH in engineering education will enable engineers to make socially sustainable decisions (Josa & Aguado, 2021).

If engineering education encourages its students to take their social responsibility seriously (Cech, 2014), how to overcome resistance, bring areas closer together and create strategies that allow them to form principles of social responsibility in future engineers (Makienko & Panamaryova, 2015)?

Research or materials on the impacts of SSH on Engineering education are relatively scarce compared to classic conceptual or technical subjects of Engineering and among the results found, some lack empirical data. Even so, this article presents the results of some studies that reinforce the importance of approximation between the areas and how Engineering can benefit from this approximation.

This article intends to bring elements that reinforce the arguments referents to the benefits of inserting the SSH of education in Engineering and is organized in such a way that the following sections present an explanation about Engineering career, followed by the importance of inserting the SSH in Engineering education. In the following, some evidence of the positive impacts of this insertion and the final considerations are presented.

2 The engineer and the Engineering career

Engineering has always aimed to create services and products to be used by humans, but not always the human being or users were in the spotlight of projects. When placing the user in the spotlight, it is necessary to consider suitability for use, which requires a strong exercise of empathy taking into account the different cultures, gender, race, social class, profession, religion and nationality (Ottino & Morson, 2016). Going further, the engineer's concern should have a broader scope focused on the interests of public welfare (Cech, 2014). This need or requirement calls for engineers who are flexible and able to easily adapt to the changes and unpredictability that the current world experiences (Ottino & Morson, 2016).

Engineers, in turn, are seen as problem solvers and team leaders, and it is necessary that they understand the different ways of thinking of people, must know how to manage the different levels of knowledge and engagement of team members, understand the diversities of team members, focus on the user of the product or service and those impacted by engineering projects (Jablocow, 2007; Boni, MacDonald & Peris, 2012). Insuch things as these, common in the daily lives of many engineers, technical knowledge must be accompanied by good professional practices that involve social responsibility that are not developed in conceptual and technical engineering disciplines (Jablocow, 2007).

When mentioning social responsibility, it is necessary to talk about ethics, but not only the ethics described in manuals of the Engineering professional. Stieb (2007), for example, places science between ethics and engineering and engineering, being responsible for converting science into technology and products, must consider ethics as part of the same system. According to Stieb (2007, p. 270) "engineering without ethics is dangerous; ethics without engineering is useless."

Considering, then, that the current times need flexible engineers, able to deal with uncertainty and concerned with the public welfare, it is worth a brief reflection of what happens during the process of education in Engineering. In Cech (2014) is presented the result of a study that demonstrates that the engagement of the engineering student in causes and social concerns decreases with the passing of the years of study and, according to a survey conducted in American educational institutions, in institutions with more traditional curricula this disengagement is more significant. Some reasons for this disengagement are presented, highlighting the fact that any non-technical considerations are considered irrelevant to the actual work of engineering within the teaching environment, a fact also observed in Josa and Aguado (2021). As if it were part of the culture of engineering education, ignoring social and humanist issues.

It seems reasonable, then, to conclude that the traditional teaching of Engineering, which in a certain way shields students from themes related to social and humanist concerns, needs a self-criticism to allow such themes to be present during the trajectory of the student in his formation process.

3 The SSH in Engineering education

The Social Sciences and Humanities (SSH) constitute the large area called "Human Sciences" and because it is the cause of some confusion, especially for those who are not native to these areas, a brief differentiation is appropriate. The humanities are the fruit of human cultural production. They are based on facts and records that shape a society's culture and the characteristics of the individual. Examples are Arts, History, Law, Letters. The Social Sciences are influenced by the Humanities and use scientific methods to try to interpret and reflect on society. CSH can be understood as the set of knowledge that will, in fact, form an engaged, critical engineer, aware of the impacts of his projects and focused on the common welfare (social sciences) (Josa & Aguado, 2021).

As mentioned earlier, part of the CSH have been present in the curricular structures of Engineering courses for a long time. The most common examples are the presence of disciplines such as Administration, Economics and Law in the curricular structures of Engineering courses. Less often the Arts are considered when one wishes to develop creativity. However, the presence of these disciplines is not enough when one wants the training of engineers with critical vision, with responsibility and social commitment.

The insertion or approximation of the CSH with the Engineering is also justified when considering the relations of the engineer in the exercise of the profession, even if the aspects of society are not considered. The more the engineer advances in his career, the more he will have to deal with people, the greater responsibility he will have over projects and consequently, the greater the impacts of his decisions. Interactions with employees, consumers and competitors increase, either directly or indirectly, reinforcing the importance of knowledge in the humanities. For example, a company leader is required to have knowledge of law, communication, business ethics, psychology, and the ability to deal with conflicts (Klochkova, Bolsunovskaya & Shirokova, 2018). As the authors point out, in certain situations or moments of the career, the following will be as important or more important: interactions with people than processes and tools; the operation and operation of the products than all the project documentation; cooperation with consumers than the terms of the contract; and the willingness to change rather than follow an original plan. That is, the skills required go beyond the ability to work and team. Knowledge and skills are needed that make it possible to interact beyond the limits of the company, because not only a project in isolation is influenced by the performance of an engineer, but the whole company.

Engineers need to understand society and the world in which they live, knowing the past that brought to current technologies to be able to drive technological change (Jablocow, 2007).

Knowing the history, enables a knowledge that leads to important decision making when it comes to a project or development of new technologies. It is important to provide the student with the opportunity to compare the technical solutions they consider in each project with historical experiences in similar projects (Klochkova, Bolsunovskaya & Shirokova, 2018). Understanding how models, theories and technologies develop, contributes to the improvement of processes and products and how a given solution can be implemented with greater effectiveness (Jablocow, 2007) and this effectiveness can be determined by analyzing the historical aspects of engineering work not only in the context of current tasks, but also in comparison with past ideas (Klochkova, Bolsunovskaya and Shirokova, 2018).

Regarding the understanding and understanding of the user and development of appropriate technologies for certain groups of users or certain societies, an example can be found in Boni, MacDonald & Peris (2012). In the text the authors address the development of empathy from a proposal of the organization Engineers Without Borders that turned into a program of the Higher Technical School of Industrial Engineering of the Polytechnic University of Valencia called Introduction to Development Aid and, as a result, at the end of the program the participating students demonstrated a greater concern with equality and justice, as well as concerns about environmental degradation.

Despite the recognition of the importance of SSH, their acceptance in Engineering courses is not so easy. There is even a certain stereotype of both engineers and professionals in the humanities that makes it difficult to imagine an integration between the areas. Engineering is seen as a course where the disciplines deal with things and not people (Jablocow, 2007).

To encourage the development of humanities, Jablocow (2007) proposes to treat the subject from the perspective of problem solving, something typical of engineering and easily accepted by engineering students. In the article, it is addressed among some benefits, the design of better products and in a faster and more efficient way. To justify its importance, arguments such as the skills needed by a leader such as those already mentioned above (conflict management, dealing with diversity, different levels of knowledge) and knowing how to deal with preferences during the problem-solving process are used. It also argues that ethical principles and social responsibility can also be associated in practices that involve problem solving.

SSH can also be addressed through extension activities always explaining social aspects, and an example is already mentioned above and developed at the Polytechnic University of Valencia. In this project, in addition to students from different engineering courses, students from other areas such as management, life sciences and arts were involved. As a result, research done with students at the beginning and end of the project demonstrated that, in addition to the concerns about social inequality and environmental degradation, students developed a greater power of argument and sense of responsibility (Boni, MacDonald & Peris, 2012).

Deal with major issues and challenges of humanity (water, hunger, natural resources) or the study of philosophy to provoke in students the questioning in different actions as well as the rhetoric that will be useful in different situations of professional life, from the presentation of a project to the management of conflicts. Problems related to the big questions are mostly complex problems that cannot be solved with just one area of knowledge. Addressing these problems in an interdisciplinary way, when more than one area of knowledge is needed to achieve a solution, is an opportunity to bring SSH to engineering education (Josa & Aguado, 2021).

On the great issues and challenges of humanity, it can be cited as an example an initiative of the School of Electrical and Computer Engineering of the State University of Campinas (UNICAMP) to offer graduate students the discipline Topics in Intelligent Systems that provokes a discussion of the impacts of technology on the great issues and challenges of humanity and how engineering can act to collaborate and impact positively and negatively on these issues.

Another example from the same institution is the discipline History and Philosophy in Electrical and Computer Engineering, also offered to graduate students and open to graduate students. The discipline provides an immersion in philosophy and theory in Electrical and Computer Engineering, through the development of texts, reviews and discussion of videos on subjects of the area and main names of Electrical Engineering and Computer Engineering. In addition, through a three-minute video produced by students on their research topics or of interest related to the areas of the discipline, students develop the power of synthesis and argumentation (Manera et al., 2013).

4 Evidence of the benefits of including SSH in Engineering education

The presentation of results that evidence the benefits of including SSH in Engineering education encounters barriers and limitations because not many studies are found presenting quantitative or qualitative results, but rather some empirical results or even positive reports, which can be influenced by issues found in institutions, such as teaching method, teaching experience or institutional resources.

In this sense, the results of two texts are presented in this section that, despite the limitations, contribute to signal that the introduction of SSH in Engineering education can contribute to an improvement in student performance. One of the texts analyzes the one hundred best Civil Engineering courses according to the QS World University Rankings (Josa & Aguado, 2021). The other analyzes engineering and medical educational institutions that incorporate at different levels and formats Humanities and Arts (National Academies of Sciences, Engineering, and Medicine, 2018).

In the case of the results presented in Josa & Aguado (2021), the authors acknowledge that there are different factors that influence position in the ranking but demonstrate that the top-ranked Civil Engineering courses are those offering the most mandatory SSH credits.

In National Academies of Sciences, Engineering, and Medicine (2018) Several works are gathered that describe or report experiences of different American educational institutions, which even with methodological limitations. Some results are presented in Table 1.

Table 1. Results or evidence.

Institution	Strategy or practice	Results or evidence
Howard University – mechanical engineering students	Option of enrolling in a multidisciplinary capstone course with students from the departments of electrical engineering, marketing (in the business school), and art (in the Division of Fine Arts).	Without empirical evidence presented, faculty highlight that students gain knowledge about the practical aspects of engineering in the workplace, develop skills in working in multidisciplinary teams, experience a transitional stage between the classroom and industry, improve communication skills and their employment opportunities.
Dwight Look College of Engineering at Texas A&M University	The first-year curriculum integrates areas such as ethics, writing, graphics, problem solving, physics, calculus, and chemistry.	The students who participated in the first-year integrated program demonstrated better critical thinking skills, performed better in calculus and physics, exhibited higher overall GPAs, developed significantly better computer skills, and greater facility to work in teams than students who completed the traditional first-year curriculum.
Colorado School of Mines	Students of the first-year curriculum integrate project modules and active-learning strategies, participate in a two-semester interdisciplinary seminar that developing and exploring the interconnectedness of appropriate topics from each of the first-year science, humanities, and engineering courses and engage in peer study group systems.	The engineering students who participated in this program graduated at rates approximately 25 percent higher than students in the traditional curriculum. In a follow-up survey 5 years later, these students indicated that their experience enhanced their academic preparation by helping them make connections among course topics, improving their critical thinking abilities, increasing their awareness of ethical issues, and strengthening their communication skills.
Olin College	The faculty of Engineering offers two options to students taking an introductory materials science course: an integrated materials science-history course co-taught by faculty in engineering and history, or a non-integrated course taught only by an engineering professor. Both options using problem-based learning.	Students who participated in the integrated course demonstrated increased motivation and engagement in self-regulated learning strategies over the term compared with students in the non-integrated course. Also, students in the integrated course self-reported using critical thinking skills in their work more frequently and had higher self-efficacy and valuing of learning tasks than students in the non-integrated course.

As reported in National Academies of Sciences, Engineering, and Medicine (2018) are gathered several works that describe or report experiences of different American educational institutions and in general, when adopting or offering content and practices related to Humanities and Arts, the following positive impacts were observed:

- Increased motivation and engagement in self-regulated learning.
- More frequent use of critical thinking skills.
- Higher self-efficacy.
- Higher value placed on learning tasks.
- Improved communication skills.
- Improved insight into practical aspects of workplace engineering.
- Improved multidisciplinary teamwork.
- Improved employment opportunities.
- Increased positive attitude toward the engineering course.
- Increased confidence for performing in the course.
- Improved team dynamics.

5 Conclusion

The discussions about engineering education have been happening practically since the beginning of the course offerings both in their form and in relation to their content, which incidentally, has been losing emphasis, without ceasing to be fundamental, for a competency-based education. These changes have been occurring with the aim of training engineers increasingly able to act in a world with increasingly complex problems that have been increasingly present in the professional life of the engineer and challenging him to find solutions that are not only technical. Engineers are being asked to take a broad and long-term look and this means considering human relations as well as environmental issues, and presenting creative and necessary but sufficient and appropriate proposals to those who will use and benefit from their projects.

It seems clear that the conceptual and technical contents characteristic of traditional Engineering Education is not sufficient to train Engineers with the profile required for the current times. However, the development of concepts related to the humanities is still insipient, except when it refers to the need for group work, good communication and resilience. To have engineers aware of their responsibilities, it is extremely important that there is an increasing integration between engineering and the humanities.

Empathy, ethics, flexibility, conflict management capacity, respect for diversity, among other skills that are increasingly essential to a complete training for an engineer to be inserted in a world where unpredictability requires quick actions and lasting solutions since thinking of something permanent seems to be impossible because we will always be limited to the knowledge we have at our disposal.

Even with the scarcity of research to empirically prove the benefits of the approximation or insertion of SSH in Engineering education and if in fact the results as greater engagement of Engineers in projects aimed at the common welfare, appropriate solutions, long-term and that leverage the benefits of a society or group of people and socially and environmentally responsible projects throughout the production chain, it is possible to find results that present evidence of the benefits of the approximation between the areas that can encourage not only more research on the subject, but, mainly, to encourage the institutions of Engineering education to promote a greater integration with the SSH.

6 References

Boni, A., MacDonald, P., & Peris, J. (2012). Cultivating engineers' humanity: fostering cosmopolitan in a technical university. *International Journal of Educational Development*, 32(1) n. 1, 179-186.

Cech, E. A. (2014). Culture of Disengagement in Engineering Education? Science, *Technology & Human Values*, 39(1), 42-72.

Jablokow, K. W. (2007). Engineers as problem-solving leaders: embracing the humanities. *IEEE Technology and Society Magazine*, 26(4).

Josa, I., & Aguado, A. (2021) Social sciences and humanities in the education of civil engineers: Current status and proposal of guidelines. *Journal of Cleaner Production,* 311. doi: 10.1016/j.jclepro.2021.127489

Klochkova, E. S., Bolsunovskaya, M. V., & Shirokova, S. V. (2018). The significance of humanities for engineering education. *Proceedings of the XVII Russian Scientific and Practical Conference on Planning and Teaching Engineering Staff for the Industrial and Economic Complex of the Region*, v. 1, n. 8604199.

Ludwig, A. C. L. (2018). As Ciências Sociais e Humanas e os Cursos de Engenharia. *Revista Ensino e Pesquisa em Administração e Engenharia*, 4 (2), 353-373. doi: 10.51923/repae.v4i2.

Makienko, M., & Panamaryova, A. (2015). Project Approach in Humanities as a Cognitive Strategy of Modern Engineering Education. *Procedia – Social and Behavioral Sciences*, 166, 415-421.

Manera, L. T., Barreto, G., Castro, C. A., Attux, R., & Santos Filho, J. C. S. (2013). História e filosofia em engenharia elétrica: Multidisciplinaridade no ensino de engenharia. COBENGE 2013 – *Congresso Brasileiro de Educação em Engenharia*, Gramado- RS.

National Academies of Sciences, Engineering, and Medicine (2018). The Integration of the Humanities and Arts with Sciences, Engineering, and Medicine in Higher Education: Branches from the Same Tree. Washington, DC: The National Academies Press. doi: 10.17226/24988.

Ottino, J. M., & Morson G. S. (2016). Building a bridge between engineering and the humanities. *The Chronicle of Higher Education*.

Stieb, J. A. (2007). On "bettering humanity" in science and engineering education. *Science and Engineering Ethics*, 13, 265-273.

Tharakan, J. (2019). Disrupting Engineering Education: Beyond Peace Engineering to Educating Engineers for Justice, *9th World Engineering Education Forum*, WEEF 2019.

Strengthening of Love and Meaning of Life in Engineering Students supported by Problem-Based Learning

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Abstract

This research aims to design a pedagogical intervention on the basis of the problem-based learning approach that contributes to strengthening the love and meaning of life in engineering students at Universidad Nacional de Colombia. This intervention is aimed at undergraduate students attending the courses of Introduction to Systems and Computing Engineering, Introduction to Industrial Engineering or Computer Programming, focusing on improving the personal and social skills of the students. The question that motivates this research is the following: How to design a pedagogical intervention on the basis of the problem-based learning approach to strengthen love and the meaning of life in engineering students at Universidad Nacional de Colombia? The principles of the PBL on which the teaching and learning strategies are based are the solution of real problems, self-learning, and team-based learning. The disciplinary content addresses three axes within emotional intelligence, namely: Motivation, Tolerance and Resilience. The intended learning outcomes in students are the following: students will be able to identify the factors that affect their emotional well-being, their needs and motivations in academic daily life, recognize the feeling of frustration, identify situations of stress and academic overload, recognize the daily responsibilities within their social environment, set real and achievable goals and actions regarding their daily university life, identify healthy relationships, recognize support groups, establish social and academic connections to develop the everyday activities at university and activate their resilience. The intervention involves three workshops related to the axes of the study. The type of research is mixed, quantitative-qualitative, and quasi-experimental.

Keywords: Active Learning; Engineering Education; Problem Based Learning; Intelligence Emotional.

1 Introduction

This research focuses on describing how the implementation of the problem-based approach contributes to strengthening love and meaning in life among engineering students at Universidad Nacional de Colombia. Students enrolling for the first time in the undergraduate programs of Systems and Computing Engineering and Industrial Engineering enroll in the subjects of Introduction to Systems and Computing Engineering and Introduction to Industrial Engineering. The subject of Computer Programming is offered to students of Engineering programs (Civil, Agricultural, Electrical, Electronics, Mechanical, Mechatronics, Systems and Computing, Industrial, Chemical and Environmental) as well.

With the implementation of the problem-based learning approach, it is expected that engineering students achieve the intended learning outcomes in coherence with the axes of emotional intelligence on which this research is addressed, namely: motivation, tolerance, and resilience. Regarding the context in which this research is addressed, it is important to point out that the Covid-19 coronavirus pandemic had disruptive cultural, social and economic effects in all countries. Particularly, regarding higher education, during the years 2020 and 2021, “the COVID-19 pandemic had a severe impact on higher education as universities closed their premises and countries shut their borders in response to lockdown measures" (Schleicher, 2020). Institutions of higher education around the world were faced with the challenge of implementing mechanisms to carry out their missionary functions remotely, using new teaching and learning strategies.

In Colombia, education was provided remotely. Students at the primary, secondary, and higher education levels had to face feelings of isolation, frustration, boredom, anxiety and stress. Universities faced the challenges posed by the pandemic and the post-pandemic focusing on the development of competencies in students and adopting innovative pedagogic and didactic strategies to achieve participatory and engaged learning with the community. Many efforts were made to include transdisciplinary and interdisciplinary approaches, breaking with rigid academic structures. Universities also tried to promote socially engaged teaching and to comply with the National Guidelines for Improving the Quality of Higher Education (Melo-Becerra, Ramos-Forero, Rodríguez Arenas, & Zárate-Solano, 2021).

During the pandemic, in the Universidad Nacional de Colombia, the Faculty of Engineering implemented an online psychological care and comprehensive accompaniment service aimed at students through its Welfare Division and the Systems and Industrial Engineering Area Directorate. During the implementation of this service, the need for preventive health actions articulated with daily and university life was observed. These actions were carried out consciously and systematically to contribute to the development of socio-emotional skills in students so that they acquire the necessary tools to face any challenges that may appear in their learning processes.

In January 2022, the Faculty of Engineering resumed in-person classes. Since then, the Welfare Division has been providing virtual and face-to-face psychological care and comprehensive accompaniment as part of a transformation process to improve engineering education. This process has been product of a joint effort of the Department of Systems Engineering and Computing and the Coordination of Computer Programming. It was determined that it is necessary to incorporate pedagogical and didactic strategies at the curricular level that promote the development of socio-emotional skills in students, in coordination with the missionary functions of the Universidad Nacional de Colombia. The main socio-emotional problems detected in engineering students in the Faculty of Engineering at Universidad Nacional de Colombia during the year 2022 are lack of motivation for the development of academic activities. low levels of tolerance for failure related to the results obtained from the assessment and evaluation of the academic process, presence of the feeling of frustration. Overestimation of their capacities and abilities reflected in the overload of registration of subjects, which exceeds their academic capacity, and lack of activation of resilience to respond to uncertain situations of daily life.

These socio-emotional problems lead to the weakening of love and the meaning of life in students. Therefore, the following research question is formulated: How to design an educational intervention on the problem-based learning approach to strengthen love and the meaning of life in engineering students at Universidad Nacional de Colombia?

To answer this question the problem-based learning approach will be implemented so that students develop problem-solving skills in the local context, self-learning, and team-based learning (De Graaff & Kolmos, 2003). The PBL approach integrates the themes of emotional intelligence, which addresses motivation, tolerance, frustration, and resilience in the human being. Likewise, the scope of the problem-based learning approach in engineering education is described, emphasizing the design and implementation of the intervention in the subjects of Introduction to Systems and Computing Engineering, Introduction to Industrial Engineering and Programming. of Computers. The third section describes the research design. Finally, section four corresponds to the conclusions.

2 Scope of the Integration of the problem-based learning approach in Engineering education: design and implementation of the intervention

The integration of the PBL approach in engineering education to strengthen socio-emotional skills is addressed through the design and implementation of an intervention. This design includes the problem-based learning model that integrates the intended learning outcomes, the thematic content focused on emotional intelligence, the definition of the teaching and learning activities to be used for the development of the activities to be carried out in the subjects, the assessment, and authentic evaluation. In the same way, the implementation of the intervention includes the scheme for the execution of teaching and learning activities during the intervention.

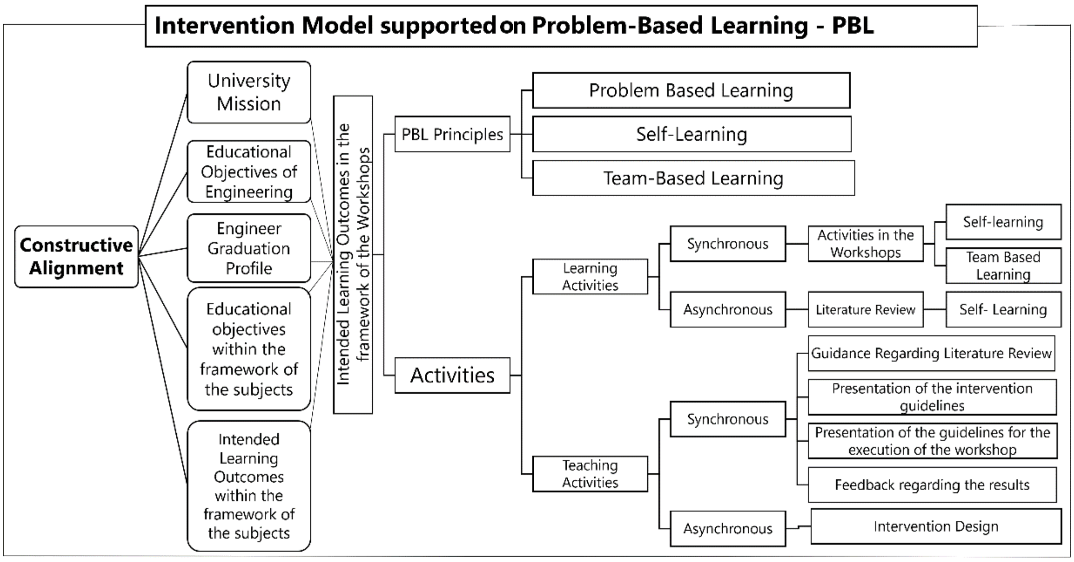

Figure 1. Intervention Model supported on Problem Based Learning – PBL based on Problem-Based Learning Supported on Flipped Classroom PBLFC (Rojas Martínez, 2021).

2.1 Design of the intervention

The intervention model considers constructive alignment, the purpose of which is to coordinate the intended learning outcomes, the teaching-learning methodologies, the assessment of the learning processes, and the authentic evaluation. The idea is to improve student learning by ensuring that there is coherence between these aspects. To conduct this constructive alignment, the missionary purposes of the university that are expected to be affected by the intervention are considered; in the same sense, the intended learning outcomes of the engineering programs are identified according to the career profile. Next, the educational objectives of the subject are identified, as well as the intended learning outcomes to which the intervention is expected to contribute. Then, the principles of the learning approach based on problems or projects on which the intervention is built are established, these are problem-based learning, self-learning, and team-based learning. The intended student learning outcomes were established in conjunction with the disciplinary content addressed for this research and focus on emotional intelligence related to motivation, tolerance and frustration, and resilience. Finally, the activities to be carried out are defined within the framework of the teaching and learning strategies. Concerning constructive alignment, there must be at least one learning activity that aims to contribute to the intended learning outcomes (Luy-Montejo, 2019). To comply with this guideline, three workshops are designed, each with a duration of two hours synchronous face-to-face. The information provided by each of these aspects is indicated in Table 1.

Table 1. Constructive Alignment – Missionary Purposes, Graduation Profile in Engineering, Subject Educational Objectives, and Intended Learning Outcomes of the Subjects.

Constructive Alignment	Description
Missionary Purposes of Universidad Nacional de Colombia	To educate professionals and researchers on a scientific, ethical, and humanistic basis, providing them with a critical conscience, in a way that allows them to act responsibly in the face of the requirements and trends of the contemporary world and lead processes of change creatively. To educate free citizens and promote democratic values, tolerance and commitment to civic duties and human rights. To promote the integration and participation of students in order to achieve the purposes of higher education.
Intended Learning outcomes associated with the graduation profile of the Systems and Computing Engineering program.	Work effectively in multidisciplinary and multicultural teams, in national and international contexts, to achieve a common goal. Understand and apply professional, ethical, social, historical, environmental, economic, and legal issues and responsibilities to guide their work. Recognize the need for lifelong learning to stay current in their profession and in other fields that allow them to understand the historical, political, social, economic, and environmental context of their work at a local and global level.
Intended learning outcomes associated with the graduation profile of the Industrial Engineering program	Social and humanistic training that leads to the analysis and understanding of the social, economic, natural, and political context, developing the ability to communicate clearly and convincingly and the attitude for teamwork.
Educational objectives of the course Introduction to Systems Engineering and Computing.	To motivate the student and place him in the best way in the social practices of the disciplines that make up Engineering and its specialization in computer systems. Provide elements to develop oral and written communication skills, teamwork, leadership, and creativity.
Intended learning outcomes in the students of the subject of Introduction to Systems Engineering and Computing.	To recognize the main challenges that humanity faces at the local level, within the framework of their daily lives. Communicate effectively and appropriately to achieve their objectives based on knowledge, aptitudes, and intercultural skills.
Educational Objectives of the Subject of Introduction to Industrial Engineering.	Help the student to recognize his potential as an engineer. Promote in the student the observation of reality with a critical sense through his capacity for analysis.
Intended Learning outcomes in Industrial Engineering students	To Promote creative appropriation to problem solving and personal and professional excellence. Communicate effectively and appropriately to achieve their objectives based on knowledge, aptitudes, and intercultural skills.
Intended learning outcomes in Computer Programming students	To recognize problems that can be solved by means of an algorithm and apply a systematic methodology for the solution.

Workshop A corresponds to the one called Motivations – Cheer up to Act. Through learning behavioral techniques, the student is expected to achieve the seven intended learning outcomes related to the themes of problem-based learning or Projects and the motivational theme that includes mindfulness, emotions, spirituality, hierarchical levels of human needs in the pyramid of Maslow and love and meaning of life that frame in the first module of the content (Cuzzolino, 2019). The activities are synchronous face-to-face except for activities two and six that are carried out asynchronously before the workshop as indicated in Table 2.

Table 2. Workshop A. Intended Learning Outcomes – Module Motivations – Learning and Teaching Activities.

Nº ILO	**Intended Learning Outcomes ILO** The student will be able	**Nº /Teaching Activities**	**Nº / Learning Activities**
1	To recognize the steps of the problem-based or project-based learning approach	1. Orientation on PBL. Synchronous Face-to-face.	2. Reading about PBL. Asynchronous.
2	To be present and aware of the environment where the activity takes place.	3. Orientation about the activities to be carried out during the workshop. Direction of the mindfulness exercise.	4. Execution of the mindfulness exercise.
3	To recognize the emotional and spiritual dimension in their daily lives.	5. Presentation of the results of the pre-test. Presentation of the results of the construction of the compass of emotions.	6. Reading about emotions. Asynchronous. Construction of the compass of emotions. Self-Learning. Synchronous.
4	To create awareness about the needs and achievements that generate motivations in themselves.	7. Orientation towards students for the construction of their own pyramid of hierarchical levels of needs.	8. Self-reflection on the components of human behavior.
5	To identify the levels of hierarchy in Maslow's pyramid of human needs.		9. Individual construction of the pyramid of hierarchy of needs.
6	To locate your own needs in the hierarchical levels of human needs in Maslow's pyramid.	11. Observation of the process of construction of the pyramid of hierarchy of needs of the students.	10. Team construction of the pyramid of hierarchy of human needs in students. Team-based learning.
7	To become sensitized about the love and meaning of life through the understanding of the needs and achievements and identification of their motivations.	13. Closing of the Workshop.	12. Shared Knowledge. Team-based learning

The workshop B is called Tolerance, a key factor in coping with frustration. With this workshop, the focus is on students acquiring techniques and tools to generate conducive health conditions, the improvement of the quality of life and the collective Welfare of the students. From the techniques and tools, self-reflection about their responsibility towards their own Welfare and quality of life is promoted in the students. Likewise, it invites students to assess the goals that have been set and the actions that must be taken to achieve them, bearing in mind the possibility of facing difficult situations, which in some cases lead to frustration. In this workshop, seven Intended learning outcomes related to the themes of human welfare are integrated, and twelve of its dimensions, namely: physical, emotional, spiritual, environmental, social, intellectual, occupational, and financial. Tolerance as the attitude and ability to face and respond to difficult situations. Finally, Frustration as a frequent emotional response to the opposition or resistance to the fulfillment of the will, which is related to the emotions of anger, annoyance and disappointment that can be caused by not achieving the fulfillment of a goal or objective of the individual. Among the types of frustration are barrier frustration where the person gets frustrated when there is an obstacle that prevents them from reaching their objective, frustration due to the incompatibility of two positive objectives that appears when there is the possibility of achieving two objectives, but these they are incompatible with each other. Alike, intended learning outcomes, learning and teaching activities are indicated in Table 3.

Table 3. Workshop B. Intended Learning Outcomes – Module Dimensions of Welfare, Tolerance and Frustration - Learning and Teaching Activities.

Nº	**Intended Learning Outcomes** The student will be able	**Nº /Teaching Activities**	**Nº / Learning Activities**
8	To describe the meanings of tolerance in the field of the attitude of the human being, as well as a capacity of the human being.	1. Guidance on reading the dimensions of welfare. Face to Face synchronicity.	2. Reading about the dimensions of welfare. Asynchronous. Self-learning.
9	To be present and aware of the environment where the activity takes place	3. Guidance on the activities to be carried out in the workshop	4. Mindfulness exercise. Self-learning.
10	To identification of problems in daily life.	7. Presentation of the results of the Identification of difficult situations or problems in daily life.	5. Identification of difficult situations or problems in daily life and of alternative solutions or ways of dealing with them. Self-learning. 6. Life stories, identification of difficult situations, presentation of a case study. Team-based Learning.
11	To recognize the dimensions of Welfare and locate in each of the dimensions of Welfare the elements that characterize it from their personal and social environment.	9. Motivating orientation about the dimensions of welfare. 12. Verify that in activities 10, 11 the students reflect and answer the guiding questions.	8. Identification of their responsibilities and those of their environment. Self-Learning, synchronous face-to-face. 10. Describe for each dimension of welfare, the responsibilities, goals or objectives, actions, and resources. 11. Value the experience Self-learning.
12	To build the dimensional octagon of Welfare.	14. Verify the construction of the octagon and the contribution in each of the dimensions.	13. Build the Octagon on cardboard and assign each face to a dimension of Welfare and include the elements that characterize it according to the consensus of the team . Team-based learning.
13	To raise awareness about love and the meaning of life through action planning in the short and medium term in each of the dimensions of welfare.	16. End of workshop	15. Socialization of the dimensional Octagon of Welfare. Team-based learning.

The workshop C, Resilience is called a possibility to overcome difficult situations. Resilience capacity is addressed from a psychological approach, understood as the ability of the human being to survive, and get ahead in the face of "difficult situations" that is also associated with "situations of crisis" or simply to the "crises" that emerge throughout life.

Difficult situations are underlying everyone, and their own personal motivations, expectations, goals, or purposes in life, and are not unrelated to situations in their personal, social, academic, or work environment, among others. The topics that are addressed are: healthy relationships, circles of support, qualities of human beings, decision making. The intended learning outcomes, learning and teaching activities, details are indicated in Table 4.

Table 4. Workshop C. Intended Learning Outcomes – Module Resilience – Learning and Teaching Activities.

Nº	**Intended Learning Outcomes** The student will be able	**Nº /Teaching Activities**	**Nº / Learning Activities**
14	To describe the meanings of tolerance in the field of the attitude of the human being, as well as a capacity of the human being.	1. Orientation about the readings. On-site synchronicity.	2. Reading about Healthy relationships, circles of support, qualities of human beings and decision making. Self-Learning.
15	To be present and aware of the environment where the activity takes place.	3. Guidance on the activities to be carried out in the workshop and Present results.	4. Execution of the Mindfulness Exercise Individual, Self-learning.
16	To detect difficult situations, one's own and those of their environment within the framework of everyday life.	6. Orientation about the activity and facilitation of the learning process during development.	5. Recognition of social influence on one's own criteria. Self-Learning.
17	To describe some of the difficult situations of their daily life that they have overcome to enter the university.	8. Facilitation and observation of the execution of the activity in teams.	7. Network connection identification of problems in the local context. Team-based learning.
18	To enunciate emotions that they have experienced during the presence of difficult situations and once these situations have been overcome.	9. Process facilitator.	8. Interprets and reacts to obstacles. Real cases of the university context. Team-based learning.
19	To recognize the resilience capacity, the thoughts and actions that can be learned and developed to achieve Welfare and quality of life.		
20	To understand how needs, motivations, difficult situations, crises, frustrations, and resilience are related, and how this understanding is a mechanism that promotes love and meaning in life.	12. Guidance in the development of the Activity	9. I get active and mobilize towards real goals. Self-Learning. 10. I execute Decisive Actions. Self-learning 11. Recognition of the importance as an individual for their personal and social development. Self-learning
21	To recognize resilience factors, among which are: defining realistic goals and the actions to execute them. identify and process the strongest feelings.		
22	To encourage a positive view of yourself by identifying strengths and abilities and propose alternative solutions to problems. Examining the mechanisms that facilitate the construction and strengthening of personal and social caring relationships that arise from love and trust, identifying their circle of support.		

2.2 Intervention Implementation

The academic period at Universidad Nacional de Colombia lasts 16 weeks, therefore workshops A, B and C are carried out in weeks 10, 11 and 12, respectively.

- Workshop A is carried out in three sessions: the first session - S1- is held with the students of the first group of Introduction to Systems Engineering and Computing $G_{1S\&CE}$, while the second session - S2 – is conducted with the students of the second group $G_{2S\&C}$ of this same program. In the third session - S3 - the workshop is carried out with the students of group 1 of Introduction to Industrial Engineering - G_{1Ind} - and group 1 of Computer Programming - G_{1CP}. Each session lasts two hours.
- The sessions of workshops B and C sessions are scheduled according to the sequence shown in Table 5.

Table 5. Sequence of workshops in the intervention.

Workshop	Week	Number of questions in the pre-test and post-test	Sessions(S)/Group (G) System and Computing Engineering (S&CE), Industrial Engineering (Ind), Computing Programing
A	10	Questions 1 to 32	S1. $G_{1S\&CE}$, S2. $G_{2S\&CE}$, S3. G_{1Ind} y G_{1CP}.
B	11	Question 33 to 45	S4. $G_{1S\&CE}$, S5. $G_{2S\&CE}$, S6. G_{1Ind} y G_{1CP}.
C	12	Questions 46-54	S7. $G_{1S\&CE}$, S8. $G_{2S\&CE}$, S9. G_{1Ind} y G_{1CP}.

This implementation integrates authentic assessment and evaluation: the assessment focuses on the measurement of the learning process in the student, and the authentic evaluation of the know-how in context.

- The evaluation of workshop A includes the oral report on the pyramid of levels and the review of the consolidated information in the constructed pyramid.
- The evaluation of workshop B is based on the evaluation of the oral report of the octagon, including the eight dimensions of well-being and the review of the consolidated information in the built octagon.
- For workshop C, the evaluation is made through the networks formed, the oral presentation of the reflection on the cases of the university context analyzed.

Regarding the evaluation of the achievement of the intended learning outcomes, it is carried out based on a written pre-test and post-test that measures the extent of the conceptualization process of the topics that each workshop includes in the students. The aim is to determine the difference between the previous concepts and the experiences that the students have on the subject before the realization of the workshop and the concepts and experiences acquired during the workshop.

3 Research Design

The target population of the intervention corresponds to the students of the Faculty of Engineering of the Universidad Nacional de Colombia enrolled in the subjects of Introduction to Systems Engineering and Computing, group one $G_{1S\&CE}$ and group two $G_{2SY\&CE}$; Introduction to Industrial Engineering, group one G_{1Ind}; and Computer Programming, group one G_{1CP}. This population corresponds to 185 students in the period 2023-1. The research follows a mixed model (Johnson & Onwuegbuzie, 2004) (Creswell, 2009), in which quantitative and qualitative methods are used simultaneously and neither of these methods is prioritized over the other (Rojas Martínez, 2021). This research also considers order in terms of sequence and corresponds to Type VII, which is characterized by simultaneous and exploratory research, and quantitative and qualitative data with quantitative and qualitative analysis (Rocco, Bliss, Gallagher, & Pérez-Prado, 2003). Therefore, our methodology is framed in a basic quasi-experimental research scheme with the experimental group as follows: Observations O_1 pre-test, X (treatment), O_2 post-test, with no control group and no random selection. X corresponds to the independent variable, which is the implementation of the problem-based learning approach for both quantitative and qualitative studies.

Data collection and analysis has three moments: before the workshop begins, during the workshop, and at the end of the workshop., The pre-test is applied at the beginning of each workshop. During the workshop, qualitative information is collected. This information is related to the levels of the Hierarchy of Needs Pyramid in Workshop A, the design of the Dimensional Octagon of Well-Being in Workshop B, and the conceptualization and mechanisms for activating resilience in Workshop C. At the end of each workshop, the post-test is applied.

The information to be analyzed quantitatively will be extracted from the closed-ended questions of the pre- and post-test of each workshop. The software tools to be used are Microsoft Office Excel, IBM SPSS Statistics 23, and the statistical software R version 4.0 (Conbranch, 1951). For the qualitative analysis, the Atlas IT tool will be used focusing on the open-ended questions (Penalva, 2003). Subsequently, the results of the information analysis will be triangulated, including the results of the evaluation of the learning process in each workshop.

4 Conclusions

Maslow’s Hierarchy of Needs is one of psychology’s most important theoretical contributions to education, linking motivation to the goal of satisfying certain needs, ranked according to their importance to well-being. It is Abraham Maslow who provides a theory of the hierarchy of human needs and how personal development, and self-realization are mobilized through their satisfaction. In the context of this research, this theory shows the importance of ensuring the well-being of the students in the situations they face in their environment. In the educational context, resilience has a leading role since each individual is responsible for measuring their own integrity and strength to be able to solve difficulties and academic and psychosocial challenges. In this process, students will be able to better understand their capacities and potentialities and develop effective responses. By providing students with tools to enhance their ability to act resiliently, the way is opened for them to maintain their creativity, take responsibility for themselves, and maintain high levels of motivation and hope for the transformation of their reality, understood as an active and transformative agent.

This research acquires special importance in terms of the exploration of emotions, since it offers the student the possibility of recognition, knowledge, self-knowledge and management of emotions, it enables the student to have elements that allow him to manage the Tolerance - Frustration pair from the field of academic to the psychosocial field, facilitating good academic performance, their permanence in the University and the construction of a good and dignified life from the consolidation of their life project. The Tolerance – Frustration pairing becomes a main axis for decision making, full participation in university life, access to knowledge and leading a healthy life. It is normal for needs to be present throughout the entire life cycle. In the educational field it is necessary to know the requirements of the individuals who are trying to educate. It is necessary to know the basic needs of people, since, to want to learn, you have to feel good and have motivations that encourage you to enrich your knowledge regardless of the teaching method. Maslow's pyramid allows us to better understand human needs and motivate students to be more efficient with their tasks.

The design of the intervention for the implementation of the problem-based learning approach to contribute to the improvement of soft skills integrated into the engineering curriculum requires the articulation and commitment of the directive stays and those responsible for comprehensive engineering education. In this case, a collective administrative and academic effort was made between the Department of Systems and Industrial Engineering, Curricular Area, the coordination of computer programming, and the Welfare Division of the Faculty of Engineering. The design and implementation of the intervention is supported in response to the socio-emotional problems that transcend the academic performance of the students detected in the coordination of computer programming, the Curricular Area, and the Welfare Division of the Faculty of Engineering. This intervention proposal was presented and subsequently approved by the Advisory Committee of the Systems and Computing Engineering Program and the Committee of the Industrial Engineering Program. Once the results of the intervention are available, it will be determined if it is feasible to intervene in the other courses of Introduction to Engineering.

References

Conbranch, L. J. (1951). Coefficient alpha and the internal structure of test. Psychometrika, 16(3), 297-334. doi:https://doi.org/10.1007/BF02310555

Creswell, J. W. (2009). Research Design. Quantitative, Qualitative, and Mixed Methods Approaches. Thousand Oaks, California: SAGE Publications. Inc.

Cozzolino, M. P. (2019). Experiences of Transformative Awe and the "Small Self" in Scientific Learning and Discovery. Doctoral dissertation, Harvard Graduate School of Education. In http://nrs.harvard.edu/urn-3:HUL.InstRepos:42081562

De Graaff, E., & Kolmos, A. (2003). Characteristics of Problem-Based Learning. (T. Publications, Ed.) Journal Engineering Education, 19(5), 657-662.

Johnson, B., & Onwuegbuzie, A. (2004). Mixed Methods Research: A Research Paradigm Whose Time Has Come. Educational Research, 33(7), 14-26.

Luy-Montejo, C. (2019). Problem Based Learning (PBL) in the Development of Emotional Intelligence of University Students. Propósitos y Representaciones, 7(2), 353-383. doi:http://dx.doi.org/10.20511/pyr2019.v7n2.288

Melo-Becerra, A. L., Ramos-Forero, J. E., Rodríguez Arenas, J. L., & Zárate-Solano, H. M. (2021). Effect of the pandemic on the system education: The case of Colombia. Borradores de Economía(1179). doi:doi.org/10.32468/be.1179

Penalva, C. (2003). III Post Codificación y Análisis de Datos Textuales: Análisis Cualitativo con Altas-TI. Working Papers(5), 3-95.

Rocco, T., Bliss, L., Gallagher, S., & Pérez-Prado, A. (2003). Taking the Next Step: Mixed Methods Research in Organizational Systems. Information Technology. Learning, and Performance Journal, 21(1), 19-29.

Rojas Martínez, S. L. (2021). The effect of problem-based learning supported on flipped classroom approach in the student's learning of Economic Engineering curse. Aalborg: Aalborg University. In https://projekter.aau.dk/projekter/files/406755472/Thesis_Sandra_Rojas_15_02_2021_MPBL_Aalborg_University.pdf

Schleicher, A. (2020). The Impact of Covid-19 on Insights from Education at a Glance 2020. OECD. In https://www.oecd.org/education/the-impact-of-covid-19-on-education-insights-education-at-a-glance-2020.pdf

Sukamolson, S. (2007). Fundamental of qualitative research. Language Institute. In https://www.researchgate.net/publication/242772176_Fundamentals_of_quantitative_research

Engaging Approaches to Explore Rigid Body Dynamics Concepts in Undergraduate Engineering Courses

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Abstract

Rigid body dynamics is often seen by students as a complex subject, especially when three dimensional problems are presented. This work reports two activities that explore kinetics and kinematics concepts in a fun manner, where students are encouraged to explore alternative solutions to real problems and develop self-learning skills. The first activity is a single day group competition of elastic powered cars. The objective is to predict how much elastic energy the propulsion system needs for the car to run through a ramp and rest at its upper stage. Work and energy are the key concepts to estimate the elastic deformation at launch. Therefore, this first activity is recommended as an introductory contest to suggest that dynamics can be enjoyable and stimulate students to actively review basic physics content. This competition is mainly suitable to be applied at courses in the beginning of the program. The cars and the ramp are made of cardboard and common office materials, allowing most institutions to reproduce the experience. The rules, ramp dimensions and car design are available in this paper. In the second activity, student groups must select a theme park attraction that involves 3D rigid body motion and calculate the acceleration of a passenger. Also, the group builds a numerical model of the attraction in a commercial software to compare analytical and numerical results. Alternatively, students may collect experimental results with their smartphones if they can access a theme park ride. The analytical approach is mandatory, but each group is free to select a numerical or an experimental source to compare. Both projects have been tested, and the feedback has been positive. Students have indicated the free choice of a ride as a motivational bonus to perform the study.

Keywords: Active Learning; Engineering project; Kinematics; Kinetics.

1 Introduction

Most engineering courses have a physics unit of study dedicated to basic dynamics concepts at the beginning of their program. Undergraduate courses associated with mechanical engineering usually offer a second subject to further explore rigid body dynamics, starting with a brief review of planar particle kinematics and ending with three-dimensional rigid body kinetics (Beer F. P., Johnston, Mazurek, Self, & Cornwell, 2015; Hibbeler, 2010; Meriam, Kraige, & Bolton, 2018), commonly addressed as engineering dynamics. It is challenging to motivate students and keep them engaged with the engineering value of that subject because it requires abstract thinking of moving systems of reference, vector algebra, differentiation of trigonometric functions in chain and operations with matrices. Engineering students often label that unit of study as complex (Magill, 1997) because of its relatively high load of lectures on laws and principles derivation. To break that label and make students active (Christie & Graaf, 2017), this work suggests a game (Baydas & Cicek, 2019) to be used in the first day and a project based learning (Kokotsaki, Menzies, & Wiggins, 2016) assignment that covers more advanced content. These activities also develop design thinking (Goldberg & Somerville, 2014) and soft skills (Kumar & Hsiao, 2007), as students must organize themselves in groups, assign roles and tasks, calculate components and eventually ask companies for information.

Contests generally create a competitive atmosphere, which reduces cooperation between teams (Paiva & Santos, 2022) and should be applied carefully. This study proposes a single day game based learning activity

(Esclusa, Cebrian, Bofill, & Gómez, 2022) to review the principle of work and energy, where the competitive atmosphere is engaging and accelerates the development of the teams.

A roller coaster project is proposed by Sloboda (2015) to create an open-ended problem where students must design a ride and estimate acceleration and normal force. A dynamics project on a slider-crank variation of the four bar mechanism using a Lego set is suggested (Cobb, Rencis, Hagglund, & Jolley, 2003). It covers planar kinematics and kinetics content and takes advantage of observations of a physical model to increase the learning reward. Those studies bring valuable reports to the community, the project suggested in this work extends the collection with the assessment of three-dimensional rigid body kinematics of an amusement park ride.

Both activities suggested in this paper aim to generate student engagement by combining the fun element with dynamics concepts. They were applied at *Insper Instituto de Ensino e Pesquisa* on mechanical and mechatronics engineering undergraduate students. The article is organised in three main sections: elastic powered cars contest, theme park ride project and conclusions. The first two main sections are divided into: learning objectives, published assignment text, student performance and teachers' perception.

2 Elastic powered cars contest

The car chassis and wheels are made of cardboard, the shafts are barbeque sticks, and the propulsion is given by a rubber band attached to the chassis and rolled around the shaft. The main objective is to power the car with the exact amount of elastic energy needed to climb a ramp and rest at an upper level. The challenge is tricky because students are not allowed to experiment on the ramp and have a limited time to deliver their cars in the launch zone. The principle of work and energy (Equation 1) is exposed on the board. Where $T = \frac{1}{2}mv^2$ is the kinetic energy, $V = mgh + k\frac{x^2}{2}$ is the potential energy, and $U'_{1\to2}$ is the work of non-conservative forces.

$$T_1 + V_1 + U'_{1\to2} = T_2 + V_2 \quad (1)$$

Students should find out they need to estimate the elastic constant k of their rubber bands and maybe add mass to the car to increase adherence between the wheels and the ground. Also, they are advised to assume all energy losses $U'_{1\to2} = -c\Delta S$ to be proportional to the travelled distance ΔS by a c factor, which can be estimated from a set of experiments on known distances ΔS without slopes $h_1 = h_2 = 0$ (Equation 2).

$$T_1 + V_1 + U'_{1\to2} = T_2 + V_2 \to 0 + k\frac{x_1^2}{2} - c\Delta S = 0 + 0 \to c = \frac{kx_1^2}{2\Delta S} \quad (2)$$

The partial tasks can be listed:

1. Estimate the elastic constant of the rubber band.
2. Measure the shaft diameter and calculate the elastic deformation x for the number of shaft turns n.
3. Experiment the car on their test tables to find c.
4. Measure the ramp and weigh the car to apply the principle of work and energy.

2.1 Learning objectives

The overall objective is to review basic physics content, both theoretical and experimental. Those partial tasks of the contest are helpful to fulfil it under an enjoyable atmosphere. Since the activity is suggested as an introduction with review purposes, no assessment rubrics are available. The whole exercise, including text presentation, car and strategy preparation and race, takes about an hour in a class of 25 students. Upon completing the activity, students should be able to apply the principle of work and energy and build a dynamics model of a prototype.

2.2 Published assignment text

Each team may be formed by up to four people and will have access to a test table and a car (Figure 1). Teams are allowed to use their personal materials, such as pencils, rulers, etc. The rubber band must be attached to the chassis and rolled around the shaft to store elastic energy. Once released, the car must run up the ramp (Figures 1, 2 and 3) and rest at the upper stage.

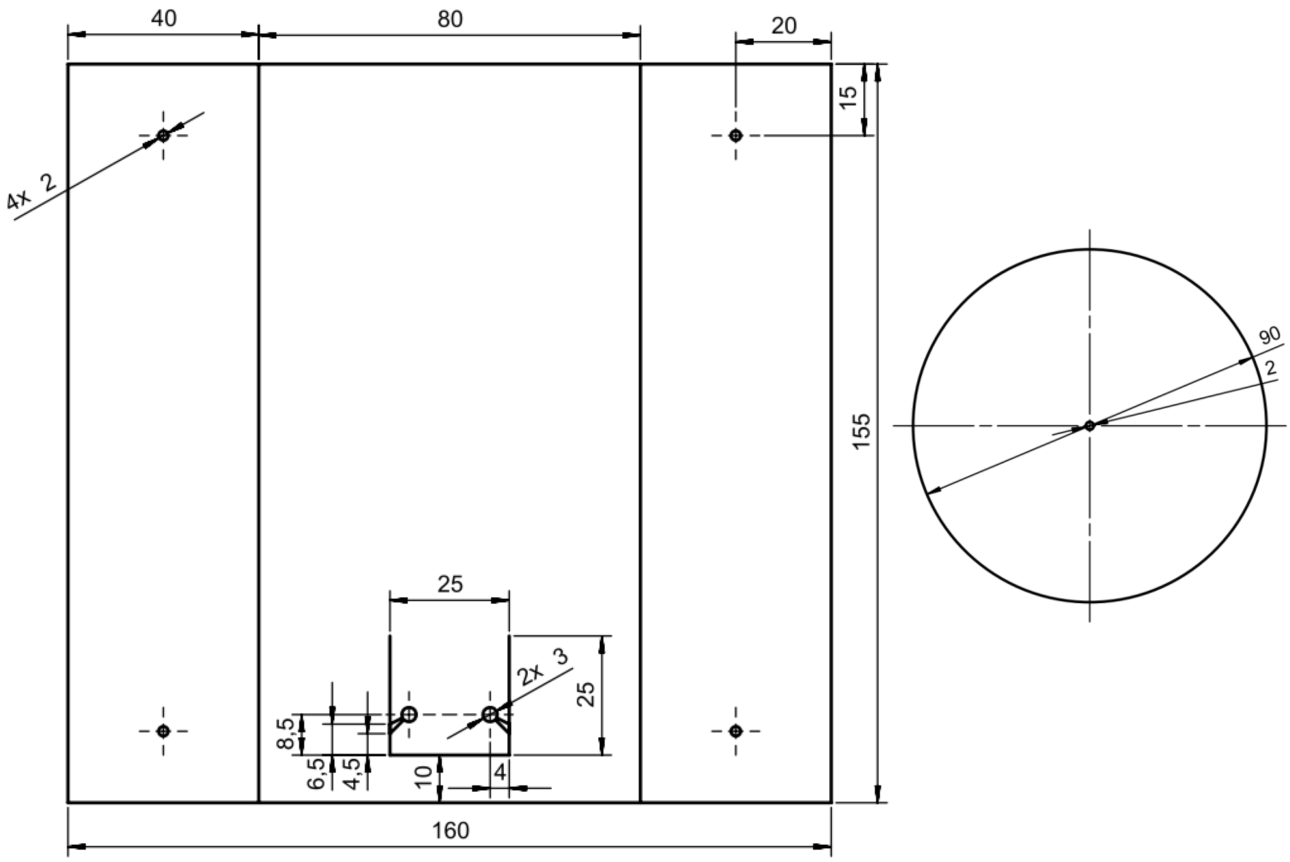


Figure 1. Cardboard car design. Units in millimeters.

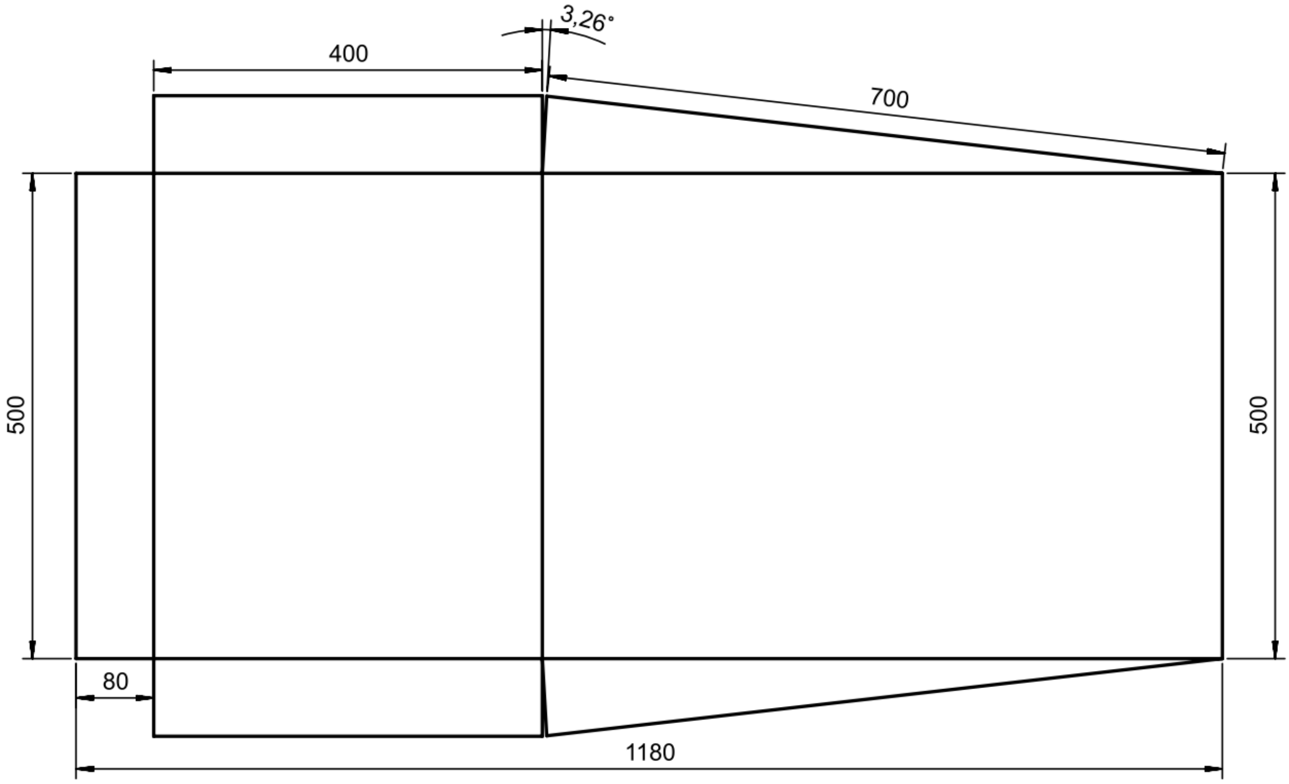


Figure 2. Cardboard ramp design. Units in millimeters.

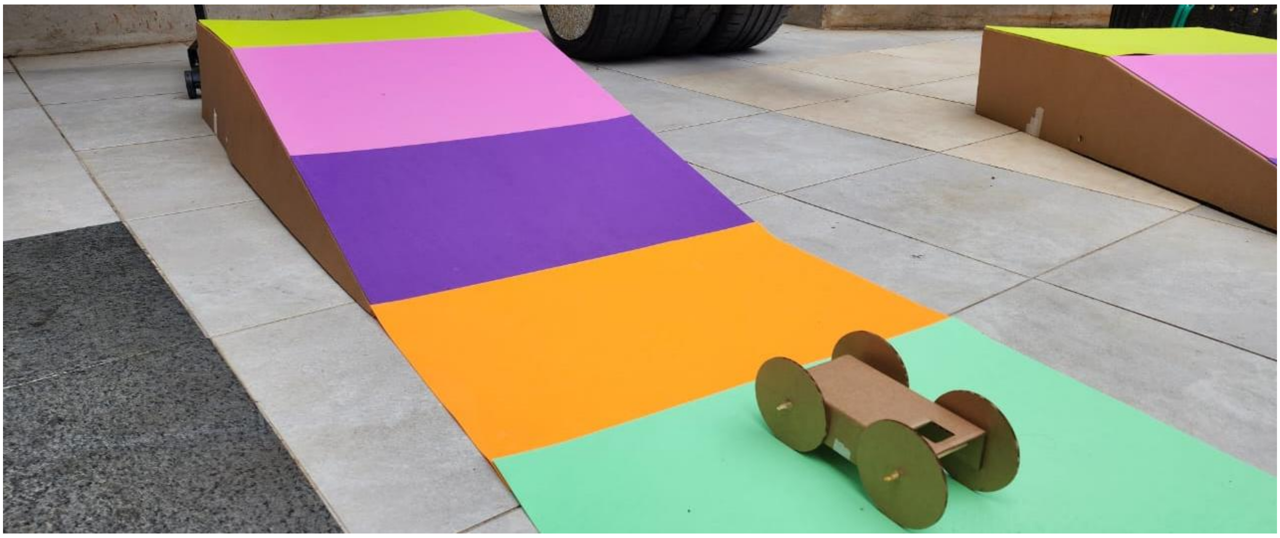


Figure 3. Car and ramp prototypes. The EVA foam cover on the ramp is recommended to increase friction.

A measuring tape and a digital scale are available at the shop for rent. A waiting line on the board indicates the rent order. Each team is responsible for writing their name on the line and returning items to the shop. Penalties are applied when a team holds equipment for more than 3 minutes (Table 1).

Table 1. Shop penalties for holding equipment for more than 3 minutes.

Equipment	Penalty
Measuring tape	-3 points
Scale	-5 points
Duct tape	-5 points

A countdown stopwatch is set for 25 minutes to prepare the car and the strategy. Each team must deliver their cars to the launch zone before the countdown ends. Otherwise, they are disqualified from the competition. Teams that deliver their cars before the stopwatch hits 4 minutes receive a 5 points bonus. The captain of each group is the only person allowed to rent equipment, enter the waiting line, and visit the launch zone to deliver the car or to examine the ramp. All other members must remain around their respective test tables. When the countdown is finished, the mechanic of each team must take their car to the launch zone, energize it, place it on the starting line and launch. Teams run according to the delivery order, in case of a draw in the final score (Table 2), the first team to run wins.

Table 2. Score table. The score does not accumulate.

Trajectory	Score
The car did not reach the ramp	10 points
The car fell from the side of the ramp	15 points
The car fell from the side of the platform	25 points
The car fell from the end of the platform	30 points
The car reached the lowest line	40 points
The car reached the middle line	60 points
The car reached the highest line	80 points
The car rested on the platform	150 points

2.3 Student performance and teachers' perception

This activity has been applied four times to a total of 76 second year undergraduate students. Nobody managed to obtain 150 points, which indicates that the contest can be considered challenging in its current configuration. The preparation time is an important factor for this activity, as it controls the difficulty level and highlights teams with synergistic collaboration.

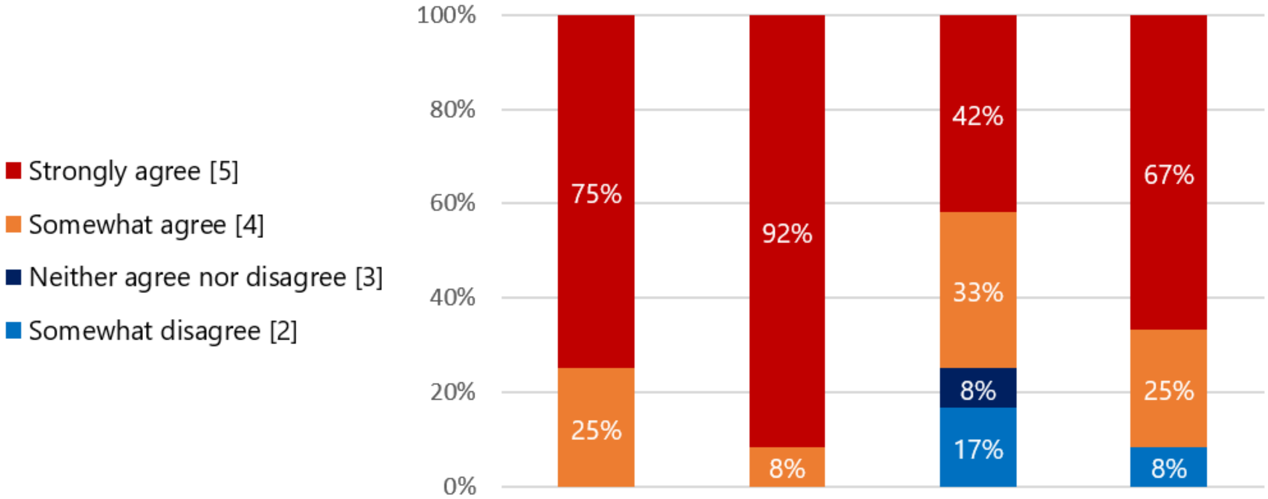
An optional questionnaire was applied to assess how effective the activity was in terms of:

- Promoting engagement and interaction among classmates in a fun and active manner.
- Reviewing basic physics content and connecting them with the learning objectives of the course.

Five levels of agreement were considered for the following questions in the survey:

Q1. The competition contributed for my engagement and active participation.
Q2. The competition promoted interaction with my classmates.
Q3. The competition allowed me to review physics content.
Q4. The competition was fun, given its physics review purpose.

Twelve students collaborated. Their responses (Figure 4) suggest the activity is effective in promoting engagement and interaction, keeping students active and attaching a fun element to the study. The competition is a bit less effective as a physics review instrument, as indicated by 16.7% of the students that somewhat disagree with Q3. Possibly, since it is a group activity, teammates reviewed physics while those students performed other roles during the contest.



	Q1	Q2	Q3	Q4
Strongly disagree [1]	0,0%	0,0%	0,0%	0,0%
Somewhat disagree [2]	0,0%	0,0%	16,7%	8,3%
Neither agree nor disagree [3]	0,0%	0,0%	8,3%	0,0%
Somewhat agree [4]	25,0%	8,3%	33,3%	25,0%
Strongly agree [5]	75,0%	91,7%	41,7%	66,7%

Figure 4. Questionnaire results by agreement level with Q1 (the competition contributed for my engagement and active participation), Q2 (the competition promoted interaction with my classmates), Q3 (the competition allowed me to review physics content) and Q4 (the competition was fun, given its physics review purpose).

3 Theme park ride project

The study of three-dimensional rigid body velocity (Equation 3) and acceleration (Equation 4) involves rotating frames of reference and lengthy vector algebra. Where subindexes A and B indicate a point of interest and the origin of a frame of reference, respectively. The position, velocity and acceleration of A relative to the frame of reference at B are denoted by vectors $\mathbf{r_{A/B}}$, $\mathbf{v_{rel}}$ and $\mathbf{a_{rel}}$, respectively, while the absolute velocity and acceleration vectors of A and B are denoted by $\mathbf{v_A}$, $\mathbf{v_B}$, $\mathbf{a_A}$ and $\mathbf{a_B}$. Also, $\mathbf{\Omega}$ and $\dot{\mathbf{\Omega}}$ indicate the angular velocity and acceleration vectors of the rotating frame of reference.

$$\mathbf{v_A} = \mathbf{v_B} + \mathbf{\Omega} \times \mathbf{r_{A/B}} + \mathbf{v_{rel}} \quad (3)$$

$$\mathbf{a_A} = \mathbf{a_B} + \dot{\mathbf{\Omega}} \times \mathbf{r_{A/B}} + \mathbf{\Omega} \times \left(\mathbf{\Omega} \times \mathbf{r_{A/B}}\right) + 2\mathbf{\Omega} \times \mathbf{v_{rel}} + \mathbf{a_{rel}} \quad (4)$$

3.1 Learning objectives

The overall objective of this project is to attach a sense of fun to the theoretical content by using a theme park attraction. Students must select an extreme ride based on 3D rigid body movement, derive the velocity and acceleration of a passenger, and compare their results with a simulation or accelerometer data. A video tutorial on a commercial CAE software is provided, and a mobile app to access accelerometer data is suggested. Teams that select the experimental approach must enter the ride carrying their smartphones. In many engineering projects, determining the kinematics is an intermediate stage, while finding reaction forces or internal stresses is the genuine objective. This project is a relatively rare case that places the kinematics itself as a final goal and extracts practical conclusions, such as passenger safety and thrill.

Upon completing the assignment, students should be able to calculate the velocity and acceleration of 3D rigid bodies relative to moving frames of reference and identify a safe source for validation. The partial tasks are listed in Table 3 and published to the students.

3.2 Published assignment text

Each team must be formed by up to four people and select a theme park attraction that involves three-dimensional rigid body movement. Using your knowledge of dynamics, calculate the velocity and acceleration of a passenger in a particular instant of interest and validate your results using numerical or experimental data. Also, suggest ways to make the ride more thrilling. A scientific poster containing the information in Table 3 must be delivered up to ten days from the publication of this text. Each section is marked according to the assessment rubrics (Table 4) (Malini Reddy & Andrade, 2010).

Table 3. Assessment tasks and weights for the theme park ride project.

Section	Content	Weight
Introduction	Presentation of the attraction containing at least one image and list of dimensions. Explain the selection of an instant of interest for the study.	20%
Analytical methods	General calculation of the velocity of a passenger at the instant of interest.	20%
Analytical methods	General calculation of the acceleration of a passenger at the instant of interest.	30%
Numerical methods	Presentation of the CAD, CAE, numerical graphs and highlight of the instant of interest.	20%
Experimental methods	Photo of the team on the ride, experimental graphs and highlight of the instant of interest.	20%
Conclusion	Results comparison and suggestion on how to make the ride more thrilling.	10%
References	---	------

Table 4. Assessment rubrics.

Incomplete (0%)	Developing (25%)	Essential (50%)	Proficient (75%)	Distinction (100%)
Section has not been presented.	Most content items or calculation steps are incorrect.	A few content items or calculation steps are incorrect.	All content items are correct, but the document is not fully clear.	All content items are presented clearly.

3.3 Student performance and teachers' perception

This assignment has been applied once to a total of 23 second year undergraduate students. The average grade was 7.4, and the standard deviation was 2.8. To estimate the dimensions of the attraction, most groups used image processing on internet videos and calibrated with known lengths in those pictures. Other groups contacted the manufacturers to ask for drawings and more precise information on dimensions and angular velocities. This kind of behaviour indicates a high level of engagement with the project. Five teams preferred to draw a CAD and perform kinematic simulations (Figure 5), while the remaining team visited a small theme park to obtain accelerometer data. Since fewer students are willing to select the experimental approach, it is beneficial to take student profiles into account when forming teams to achieve better results.

The NX Siemens pack is available for students at Insper, but most CAE tools offer free student licenses for a limited period. Also, there are several free apps for Android and IOS that collect accelerometer information.

Therefore, the materials required to apply this project are accessible. In previous versions of this assignment, the attraction was available in the text, and all teams had to analyse the same ride. The change in rules to allow a free choice of a ride was made based on student feedback, as many groups had demonstrated interest in analysing specific attractions.

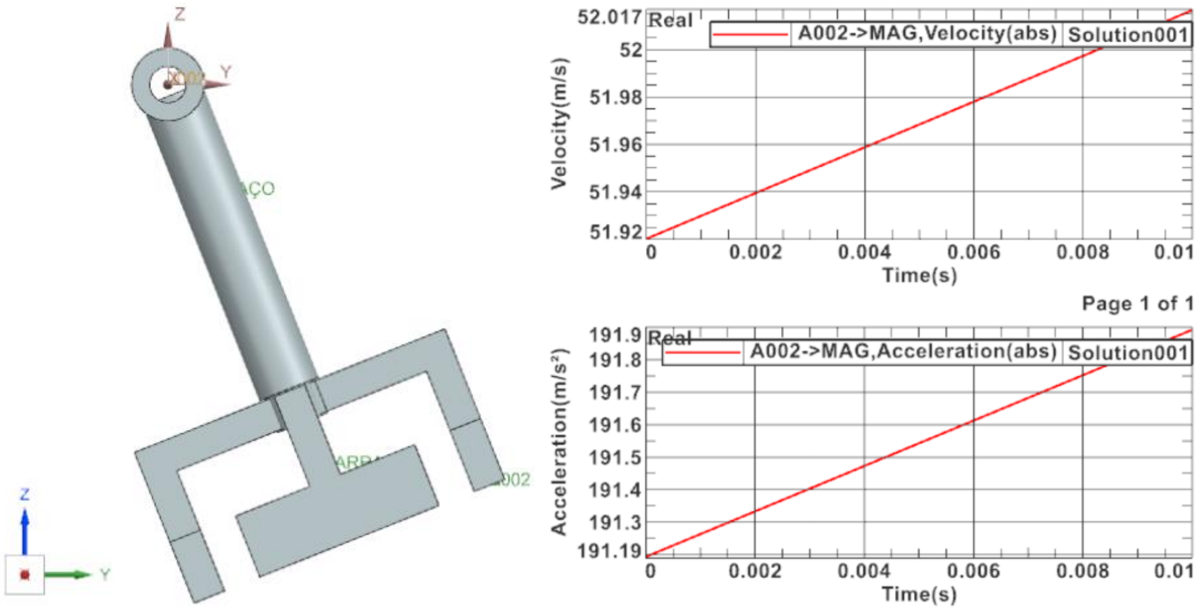


Figure 5. Example of numerical analyses performed by students. The timespan is short because the mechanism starts the analysis in the position of interest.

4 Conclusion

Engineering dynamics is usually challenging to create student engagement because it is associated with a relatively high load of theoretical lectures and requires abstract thinking to be fully understood. Two activities that seek to attach an element of fun to the study of dynamics are reported. These reports contribute to a larger collection of educational activities in engineering that promote design thinking and soft skills development. The elastic powered cars contest reviews basic physics content, we suggest its application as an introductory exercise. The theme park ride project is a ten day assignment focused on 3D rigid body kinematics. Based on student behaviour, questionnaire outputs, deliveries and report quality, a high level of engagement was observed in both assignments. Also, the materials required to apply them are simple, allowing most institutions to reproduce and adapt. Future steps include collecting more precise feedback data and improving both activities. Also, the elastic powered cars contest can be adapted into a longer project, with more sophisticated objectives, involving rigid body kinetics instead of particles, and sharing tasks with other units of study.

5 Acknowledgements

The authors thank the Insper FabLab technicians and leadership for their insights on the contest and manufacturing the cardboard cars.

6 References

Baydas, O., & Cicek, M. (2019). The examination of the gamification process in undergraduate education: a scale development study. Technology, Pedagogy and Education, pp. 269-285.

Beer, F. P., Johnston, E. R., Mazurek, D., Self, B. P., & Cornwell, P. J. (2015). Vector mechanics for engineers: statics and dynamics (11 ed.). New York: McGraw Hill.

Christie, M., & Graaf, E. (2017). The philosophical and pedagogical underpinnings of Active Learning in Engineering Education. European Journal of Engineering Education, 5-16.

Cobb, E. C., Rencis, J., Hagglund, R. R., & Jolley, W. O. (2003). A fun and challenging engineering dynamics project using a lego construction set. Annual Conference (pp. 8-50). Nashville: ASEE Peer.

Esclusa, M. F., Cebrian, J. A., Bofill, P., & Gómez, M. H. (2022). Game-based learning vs gamification: a hands-on. International Symposium on Project Approaches in Engineering Education; Active Learning in Engineering Education Workshop; International Conference on Active Learning in Engineering Education (PAEE/ALE'2022). Alicante.

Goldberg, D., & Somerville, M. (2014). A whole new engineer. The coming revolution in Engineering Education.

Hibbeler, R. C. (2010). Engineering mechanics: dynamics (12 ed.). Upper Saddle River: Pearson Prentice Hall.

Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of the literature. Improving Schools, 267-277.

Kumar, S., & Hsiao, J. K. (2007). Engineers Learn "Soft Skills the Hard Way": Planting a Seed of Leadership in Engineering Classes. Leadership and management in engineering, 18-23.

Magill, M. A. (1997). Classroom models for illustrating dynamics principles part II, rigid body kinematics and kinetics. Annual conference (pp. 2-102). Milwaukee: ASEE Peer.

Malini Reddy, Y., & Andrade, H. (2010). A review of rubric use in higher education. Assessment & Evaluation in Higher Education, pp. 435-448.

Meriam, J. L., Kraige, L. G., & Bolton, J. N. (2018). Engineering Mechanics: Dynamis (9 ed., Vol. 2). Hoboken: John Wiley & Sons, Inc.

Paiva, V. S., & Santos, C. R. (2022). Project based learning approach in the heat transfer course for undergraduate students. International Symposium on Project Approaches in Engineering Education; Active Learning in Engineering Education Workshop; International Conference on Active Learning in Engineering Education (PAEE/ALE'2022). Alicante.

Sloboda, A. R. (2015). A roller coaster project as part of an undergraduate dynamics course in mechanical engineering. ASEE Annual Conference & Exposition (pp. 26-104). Seattle: ASEE Peer.

Evaluation of Students' Performance of a Project-Based Learning Course on Elements of Computing Systems

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Abstract

Both summative and formative assessments have been used in an elements of computing systems course, whose objective is to give a basis on the computer architecture, to evaluate the students' learning. For the summative assessments, practical tests have been individually applied to students in scheduled class periods, whereas for the formative assessments, a continuous integration approach has been combined with a project-based learning strategy, allowing students to collaborate into a shared repository with version control, quick feedback using automatic testing, and team awareness of the project progress. The project is executed based on an agile development strategy, allowing for teamwork skills development, and it consists of building a computer from basic hardware, using a hardware description language. Moreover, the software to be run in the built computer are also created by the students, using a course specific machine, assembly, and virtual machine languages. This work aims at evaluating the performance of students from different classes during the period from 2021 to 2022. It is worth noting that, due to the restrictions caused by the COVID-19 pandemic, one of the classes was hybrid, in which students could take the class either in person or remotely, by video conference, depending on the student's preferences or necessity. The other classes were exclusively taken in person. Results of both summative and formative assessments have been used to analyze the students' engagement with the project development, the overall performance during the course, and the relation between the project development and the performance in the individual tests. Results show that the teamwork has not been as effective in the hybrid course, as in the ones taken in person, resulting in a wider spread between the grades of students in the same group. Moreover, the students' engagement does not seem to be affected by the modality of the course.

Keywords: Project Based Learning; Student engagement; Formative assessment; Continuous Integration.

1 Introduction

Summative assessments applied in scheduled class periods have been traditionally used to ensure that students are effectively learning during a course. However, the students may only be aware of their learning status lately, which cannot leave enough time for a recovery process. Alternatively, formative assessments can provide students with quick feedback showing students' strengths and weaknesses, improving the learning process (Shute, 2008). Nevertheless, the fast and constant feedback required might be difficult to achieve owing to the number of involved students and the number of tasks in a project-based learning (PBL) course. To overcome this issue, the Continuous Integration practices (Shahin et al., 2017) can be used. In this strategy, programmers can submit their codes to a shared version control repository, where they are checked automatically by a software service, evaluating the submission continuously (Soares, & Ferrão, 2018).

The course analyzed in the work is an elements of computing systems one, which is taken by students in the third semester of computer engineering. The reference of this course is the book "The Elements of Computing Systems: Building a Modern Computer from First Principles" by (Nisan, & Schocken, 2005). The course follows a PBL methodology (Adderley et al., 1975, Blumenfeld et al., 1991, Helle et al., 2006) and aims at developing a computer starting from the transistors and introducing the computer architecture (Soares, Achurra, & Orfali, 2016). It is worth noting that PBL has been applied to different computer organization and architecture courses in literature, such as Nayak *et al.*, 2021, in which the authors' teaching experiences have been analyzed; Spertus,

& Kurmas, 2021, which have used projects considering a mastery-based grading; and Moreno-Ruiz *et al*, 2019, that have combined flipped-classroom, formative and continuous assessments, and PBL.

In this work, the performance of students from different classes of the second semester of 2021 (2021-2) and of the first and second semesters of 2022 (2022-1 and 2022-2, respectively) have been analyzed. Owing to the restrictions caused by the COVID-19 pandemic, the 2021-2 class was performed in a hybrid format, in which students could choose between taking the class in person or remotely, by video conference, using MS Teams®. The 2022-1 and 2022-2 classes were exclusively taken in person. It should also be pointed out that 2021-2, 2022-1, and 2022-2 were taken by 43, 49, and 34 undergraduates, respectively. In the course, four summative assessments were performed (approximately one per month), whereas eight formative assessments (each run for approximately one week and a half) were accomplished. The results of both assessments have been used to analyze the overall performance during the course, the students' engagement with the project development, and the relation between the project development and the performance in the individual tests.

Besides this introduction, Section 2 presents the course structure, Section 3 explains the assessments in the course, whereas the results are analyzed in Section 4. Since the course was student-centered, the students could go beyond the formative assessments' objectives, depending on their engagement. Therefore, some outstanding performances are presented in Section 5, whereas the conclusions are presented in Section 6.

2 Course Structure

The main objective of the course is to collaboratively develop a simple computer starting from the transistors up to the virtual machine language (Soares, Achurra, & Orfali, 2016), integrating execution and programming layers. While developing, it is expected that the students could understand how data and instructions are stored and treated in computers, as well as understand topics related to computer performance and operation. The computer development was divided into eight Supervised Practical Activities (SPA), as shown in Figure 1, which were executed following a bottom-up approach. Each SPA is tested using Continuous Integration practices (Shahin et al., 2017), where the codes are checked automatically using Python scripts (Soares, & Ferrão, 2018).

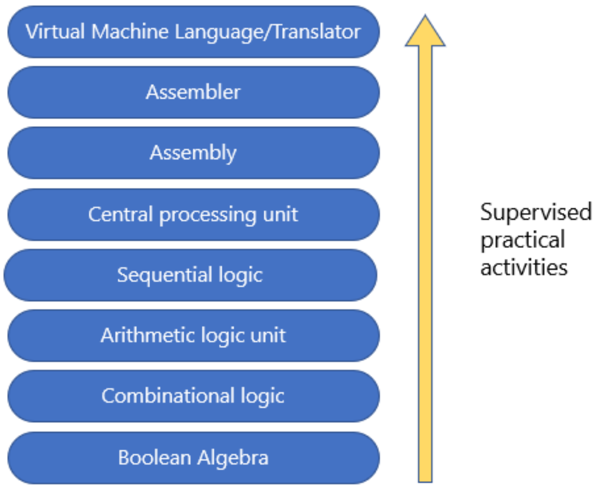

Figure 1. Supervised practical activities performed in the course.

The first SPA is related to Boolean Algebra, in which students are expected to obtain and minimize the Boolean expression for a given problem. In the sequence, they are expected to physically mount the expression using either transistors or integrated circuits. Since students have no prior knowledge of Boolean Algebra, this SPA provides an initial basis for the course and demonstrates the dynamic that is used during the entire course. In SPA #2, labeled Combinational Logic, logical blocks, such as multiplexers, demultiplexers, barrel shifters, and

16-input OR/AND/NOT, are created using a Hardware Description Language (VHDL). Moreover, arithmetic blocks such as full-adder, 16-input adder, incrementor, and comparator are implemented in SPA #3, where the previous blocks are joined to form the arithmetic logic unit. In the fourth SPA, sequential logic has been used to create memory units, such as registers and Random Access Memory (RAM). The arithmetic logic unit and the memories are used in SPA #5, to form the central processing unit (CPU), and its control unit, which is responsible for decoding the machine language into hardware operations. Besides the automatic testing using Python scripts and GHDL open-source simulator, these blocks from SPA #2 to #5 are also implemented in the DE0-CV Board Terasic Field-Programmable Gate Array (FPGA) to practically verify the functioning of the codes.

The last three SPA are related to the software that is going to run on the computer created by the students. In SPA #6, codes using a specific assembly language are developed for the course computer, where a reduced instruction set is given. In the seventh SPA, the translation between assembly and machine languages is the main objective. With both SPA #6 and #7, it is expected that students will understand the trade-off between instructions length and the number of instructions, and between code size and hardware complexity. The last Supervised Practical Activity is the use of a virtual machine language and its translation to the assembly one. In this case, students are expected to understand the concept of stack memory.

Besides the continuous integration strategy, flipped-classroom has been used, such that students should get prepared before class by reading the suggested pages and watching the indicated videos. An open website is maintained for the students, with all material needed to conclude the required tasks as well as links to external resources to complement the learning. The material is divided into theory, laboratory, and project sections. For every class, an agenda has been issued on the website, indicating the pages that should be read before the class and the activities to be performed during it. At the beginning of the class, a revision is performed, taking about a quarter of the class time, aiming to verify if the required concepts have adequately been understood. The remaining time is used to perform laboratory or project activities. Therefore, the flipped-classroom can help to assure more efficient use of time for SPA planning, objectives identification, and discussions.

Moreover, the adopted strategy also includes agile principles (Beck et al., 2001), which are commonly used in software development and consists of working in short sprints. This strategy values individuals and interactions, software development and responding to changes over processes and tools, comprehensive documentation, and following a plan. Therefore, it quickly adapts to changes and encourages communication among the members of the group. Each SPA becomes a Scrum sprint, in which a different student becomes the Scrum Master. Therefore, all students in all groups face facilitator and developer roles.

The SPAs have been applied in GitHub Classroom, based on a repository supplied by the professor, which has some basic code implementation and tests procedures that allow for monitoring the activity progress.

3 Student Assessment in the Project

Both formative and summative assessments (Taras, 2005, Villamañe et al, 2020) are used in the course to evaluate undergraduates' performance. For the formative assessments, both group and individual performances in each SPA are evaluated. It is worth noting that the SPAs are considered to be formative assessments since students receive constant feedback, which can be used for subsequent activities. Two types of feedback are used: automatic tests using Continuous Integration practices, which indicate the parts of the codes that have been correctly implemented, and the professors' feedback given at the GitHub Classroom feedback pull request, which can be used to indicate errors in the codes and suggestions for the improvement of the codes. The automatic tests can be retaken without penalty as many times as needed to obtain a working code, similar to Spertus, & Kurmas, 2021.

For each activity, the group grade rubric is presented to students, with the pattern shown in Table 1. For the SPA individual grades, the facilitator is evaluated in terms of creating and assigning issues, managing pull requests, and supporting group development. The facilitator can also self-assign code development, but this should be his or her decision aiming for the best group performance. Moreover, developers should hand in the assigned codes, submit pull requests and follow the group development. To analyze their conduct, they are requested to fill out a form, in which several project topics are rated by the group member. Developers and facilitators evaluate each other work.

Table 1. Project group grade rubric.

Grade	Rubric
A+	Advanced – additional problems/challenges are proposed. The students may also have to modify the test routines according to their needs.
B+	Proficient – expected knowledge. Besides the basic blocks, students are expected to modify them and/or combine some of them for a more complex function.
C+	Essential – students have demonstrated the minimum accepted knowledge. All the basic blocks required for the computer to work have been successfully implemented.
D	Development – there are some fails, but the students are engaged in reaching the objectives.
I	Unsatisfactory – the activity has not been successfully concluded.

Besides the formative assessments, summative ones have also been used to grade undergraduates' performance individually. Four assessments were applied during the semester (approximately one per month), whose scores were divided into two main topics with the same weights: hardware and software. The former includes all the blocks' descriptions using the Hardware Description Language, including combinational logic, sequential logic, arithmetic logic unit, control unit, and central processing unit. The Boolean Algebra has also been included in this topic since logic expressions are created using transistors and integrated circuits in the first Supervised Practical Activity. The software topic includes programming the computer in Assembly, in Virtual Machine Language, and translations between Assembly/Machine Language and Virtual Machine Language/Assembly. Editing the continuous integration tests and analyzing their waveforms results have also been considered as a software topic.

To be approved in the course, a minimum computer developed by the group must be at least functional and each student should demonstrate minimum knowledge in both hardware and software topics. Two grades are assigned to each student, one for each assessment type. The final grade is obtained by the mean between them. Figure 2 summarizes the overall assessment method used in this course.

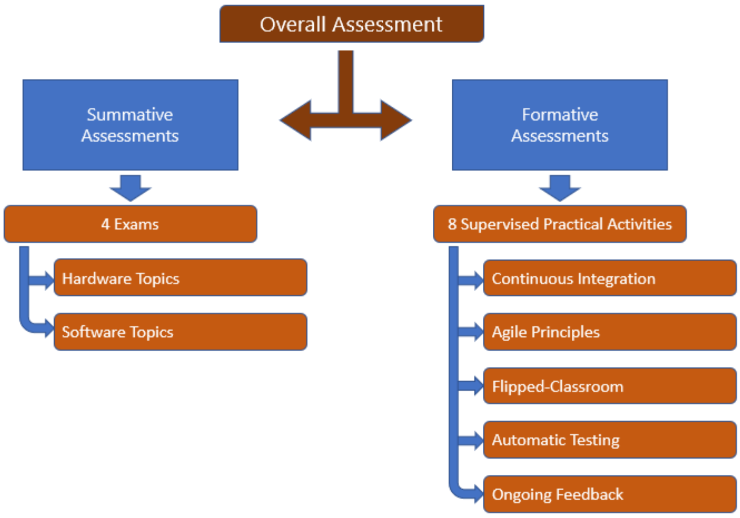

Figure 2. Assessment method applied to the course.

4 Results

To compare the performance of the different classes and to analyze the engagement between students, the results of both assessments have been considered for the classes of the second semester of 2021 and the first and second semesters of 2022. As already mentioned, the 2021-2 class was taken in a hybrid format, in which undergraduates could choose between taking it in person or remotely, by video conference. The other classes were taken exclusively in person. In Figure 3, the histograms of the hardware and software points obtained by the students along the four summative assessments are shown. To be approved, students are required to obtain at least 50 points out of the 100 maximum points in each of the topics. It should also be pointed out that the first two exams are mainly hardware-related (~70%), whereas the latter exams are focused on software since it is necessary to obtain a working computer to run a code. As can be observed in Figure 3, the grades profile in 2021-2 has been significantly different from the other semesters, presenting a flatter profile. Remarkably, a significant number of students have obtained a grade between 0 and 10 (out of 100 points) for the software in 2021-2. Since, the first exams focused on the hardware, some students that could not obtain a good performance have reduced their dedication to the course or even given up. This number has been reduced in the subsequent semesters, where the classes were taken in person, where there is a closer relationship between professors/undergraduates.

Moreover, most of the students in 2022-1 and 2022-2 have obtained both hardware and software points between 50 and 80, which represents the interval between essential and proficient knowledge. When comparing only 2022-1 and 2022-2 classes, different grades' distributions can be observed (although the difference has not been so significant as for 2021-2). Although the SPAs' objectives have been the same through the analyzed semesters, their implementations have had small variations between different semesters, such as adequation to the semester calendar, whose number of classes can be affected by holidays. Also, it could be pointed out that in all semesters at least one student has demonstrated advanced skills.

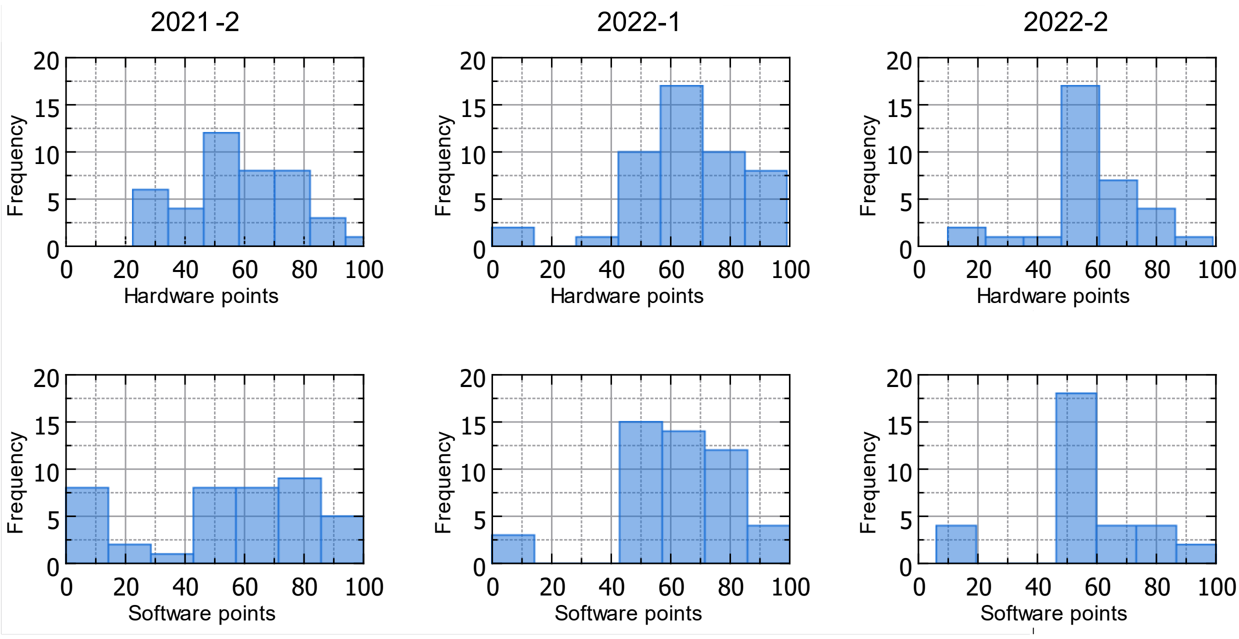

Figure 3. Histograms for the hardware and software points in the summative assessments obtained for the different semesters.

In Figure 4, the grade for each supervised practical activity is presented, where each line represents a group in the class. In this case, the grades shown in Table have been converted to the numeric format, where A+, B+, C+, and D have been substituted by 10, 8, 6, and 3, respectively. It can be observed that, in general, group engagement has been maintained along the course for the analyzed semesters. It is worth mentioning that the students' engagement has been considered to be proportional to the SPA grade. For the individual grade, it has basically been considered if the students had performed their roles, such as managing pull requests, and supporting group development. The codes for higher group grades require more dedication since they have a higher implementation complexity. However, the required knowledge is generally the same for C+, B+, and A+ grades, such that the grade could be related to undergraduates' engagement. There are only a few groups whose performance has reduced at the last SPA, which may be related to the period of the final exam of all courses, when students may choose which exam or practical activity to prioritize. It should also be pointed out that all groups have developed a minimum computer and respective software, such that all of them obtained at least a mean grade of C+ on the formative assessments. However, as pointed out by Nayak et al, 2021, it is difficult to evaluate each undergraduate performance only by analyzing groups' activities. Therefore, the relation between the formative and summative assessments is presented in Figure 5, using boxplots.

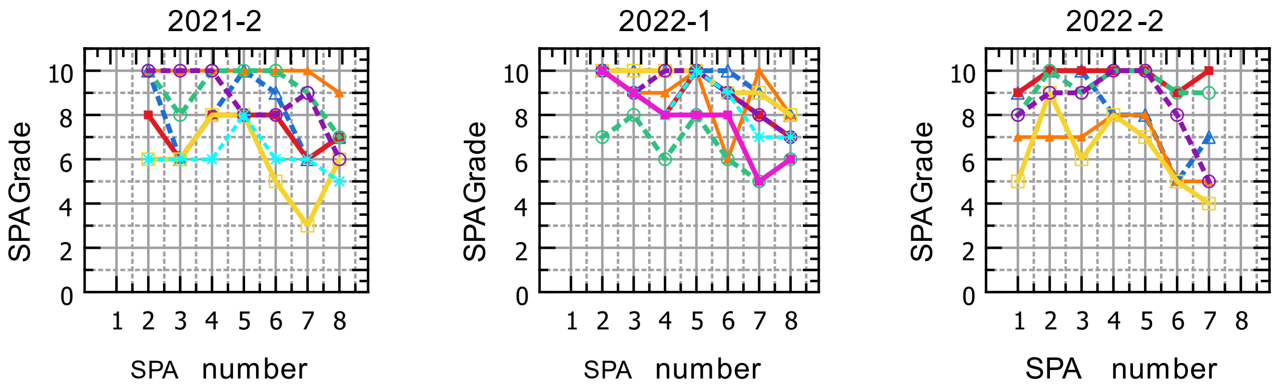

Figure 4. Supervised practical activity grade for each SPA. Each line represents a group in the class.

As it can be observed, at the classes of 2022-1 and 2022-2, there is a clear relation between the two grades, i.e. students in groups with a higher engagement in SPA have obtained a higher mean grade in the summative assessments, indicating more effective learning. Besides that, for the 2021-2 class (in hybrid format), there is no clear relationship between the grades, and a higher dispersion in the summative grades can be observed. This can indicate that teamwork has not been so efficient in the hybrid class, such that there is uneven learning inside a group. This could suggest that the dynamics inside the classroom in the way the course was initially proposed is essential to engage students in the projects. The exchange of knowledge between undergraduates occurs more effectively inside the informatics laboratory, where they could make mistakes and understand together with their team how to move toward the desired solution. During hybrid classes, students who made mistakes tried to find solutions on their own, having little contact with their colleagues, which impaired the experience exchanges that are essential in the learning process in this course. Moreover, in the hybrid classes, students engaged in activities mostly during the class period and most of them neither attended the office hours nor asked for help outside of class hours. This is different from the face-to-face model, where the students occupy the laboratory to do the activities. In this way, it seems that undergraduates of the 2021-2 class spent less time in the SPA development, which may have impaired their understanding of some concepts.

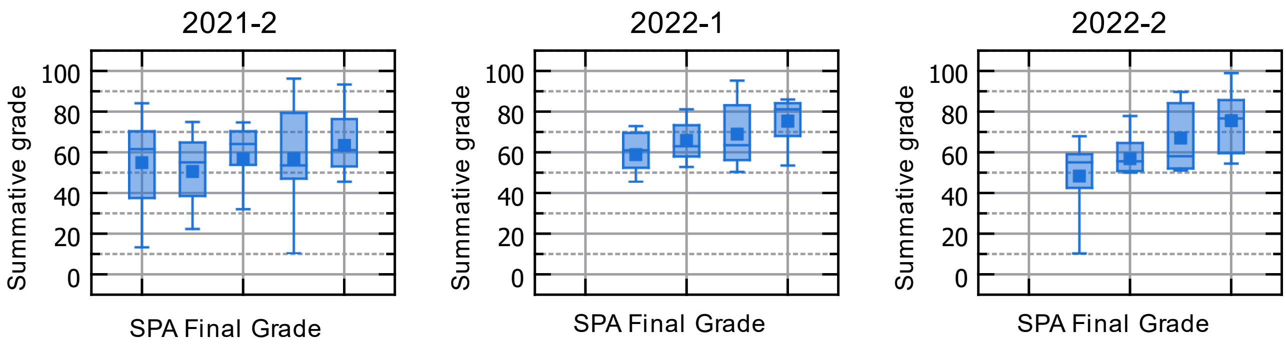

Figure 5. Relation between the summative (at the exams) and the formative (at the supervised practical activities) grades.

To deeper analyze the students' participation, the statistics for the undergraduates with a SPA Final Grade of 9 in 2021-2 has been extracted from the GitHub repository. This group has been selected since it presented the higher dispersion among all classes. Table 2 shows the contributions of this selected group. As can be observed, although these students have obtained a high grade in the SPA, there is a significant difference between their contributions. While the student that most contributed performed 26 commits, the one that least contributed performed only 2, meaning that he/she has not written codes in all SPAs. Moreover, the results also demonstrate that some students provided only a few additions to the codes, also indicating a negligible contribution to the overall performance of the group, which has been considered advanced. It should also be pointed out that the maximum number of additions is significantly higher than expected, indicating the code modifications have not been efficiently performed in this case. When finishing each SPA, students are required to fill a form to evaluate both group and individual performances. Moreover, they can also provide feedback on the course. Undergraduates, who have reported difficulties in the SPA implementation, complains about the extensive content of the course, the relatively short delivery time, and their lack of previous knowledge of VHDL. However, the methodology applied has not been the focus of complaints. Indeed, the methodology has shown to encourage active student participation, similar to Moreno-Ruiz et al, 2019.

Table 2. Contributions of the undergraduates with a SPA Final Grade of 9 in 2021-2.

Contribution metric	Mean	Median	Maximum	Minimum
commits	14.9	16	26	2
additions	2364	293	17954	54
deletions	1200	114	6809	9

5 Outstanding performances

For obtaining A+ grade in a Supervised Practical Activity, advanced exercises or challenges are proposed. In some of them, only the objectives of the activity are proposed, without giving significant information on how it should be implemented, such that students should choose the best way. In one of these activities, undergraduates are asked to modify their arithmetic logic unit to include a barrel shifter, which could be used to facilitate the multiplication of integers, that is not currently performed at the hardware in the simplified CPU (only by software). Generally, groups implement this modification in the ALU inputs, using the second input for controlling the shift. In 2022-2, one of the groups proposed the inclusion of three-barrel shifters, one at each input and another at the output of the ALU. The students have also modified all the subsequent projects to accommodate their arithmetic logic unit version, including the central processing unit, the machine and assembly languages, and the translator. Besides that, the CPU has also been modified to include a new register, providing higher flexibility in the calculations. All these modifications can deeper the understating of the trade-offs between instructions length, the number of instructions, code size, and hardware complexity.

When programming the computer using Assembly, some exercises include the use of an LCD display, which is considered a memory extension, such that the bits to be lighted on or off should be passed through the code. One of the advanced exercises asked to write the first letter of the group name in the display, meaning the students should indicate all pixels to be lit on to form the letter. To simplify this time-consuming task, two groups of 2022-1 have proposed different solutions: one considered mapping an image file to the display memory, using knowledge acquired in previous courses, whereas the other one used PyGame library to create an interface in which an image could be drawn and, in the sequence, loaded to the LCD display. Figure 6 shows the implemented user interface and also the corresponding image formed in the FPGA LCD display.

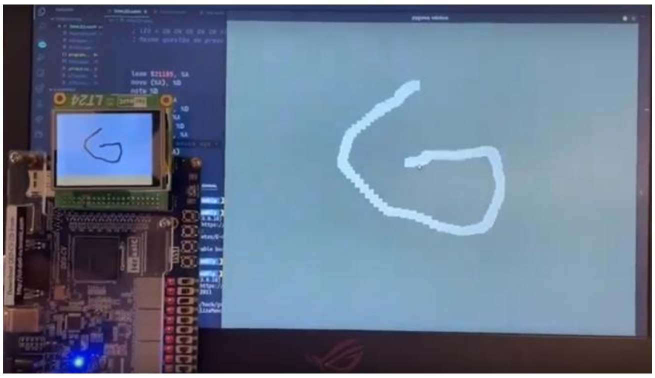

Figure 6. Example of an advanced performance, where students have created a graphical interface for writing to the FPGA LCD display.

6 Conclusions

This work has evaluated the students' performance on an elements of computing course, which aims to introduce the computer architecture to undergraduates of third semester of Computer Engineering. In the course, both summative and formative assessments have been used. For the former, four exams have been individually applied, whereas, for the latter, eight Supervised Practical Activities were applied to groups. The overall activities' objective is to build and program a simple computing throughout the semester, which has been divided into smaller tasks in each activity. Classes from three semesters have been analyzed. Two of them were taken in person, whereas the third was performed in a hybrid format (in-person plus video conference) due to the COVID-19 pandemic restrictions.

Results show that in the semester taken in a hybrid format, a higher number of students have reduced their dedication to the course or even given up, when not obtaining a good grade in the first half of the discipline. This number has been reduced in the face-to-face semesters. Group engagement has been maintained along the course for the analyzed semesters, although there are a few groups whose performance has reduced at the last activity, which may be related to the period of the final exam of all courses. Besides that, all groups have developed a minimum computer and respective software, reaching the main course goal. When analyzing formative and summative assessments together, a clear relationship between the two grades for the face-to-face semesters is observed, i.e. students in groups with a higher engagement in the activities have obtained a higher mean grade in the summative assessments, indicating more effective learning. However, for the semester in the hybrid format, a higher dispersion in the summative grades can be observed, indicating that teamwork has not been so efficient in the hybrid class, such that there is uneven learning inside a group.

7 References

Adderley, K., Askurin, C., Bradbury, P., Freeman J., Goodlad, S., Greene, J., Jenkins, D., Rae, J. and Uren, O. (1975). Project Methods in Higher Education. SRHE working party in teaching methods. Techniques group. Guildford, Surrey, Society for research into higher education.

Beck, K., Grenning, J., Martin, R. C., Beedle, M., Highsmith, J., Mellor, S., van Bennekum, A., Hunt, A., Schwaber, K., Cockburn, A., Jeffries, R., Sutherland, J., Cunningham, W. Kern, J., Thomas, D., Fowler, M., & Marick, B. (2001). Manifesto for Agile Software Development. Agile Alliance. http://agilemanifesto.org/

Blumenfeld, P.C., Soloway, E., Marx, R.W, Krajcik, J.S., Guzdial, M. & Palincsar, A. (1991). Motivating project-based learning: sustaining the doing, supporting the learning, *Educational Psychologist*, 26, 369–398. doi: 10.1080/00461520.1991.9653139

Helle, L., Tynjälä, P. & Olkinuora, E. (2006). Project-Based Learning in Post-Secondary Education – Theory, Practice and Rubber Sling Shots. *High Education*, 51, 287–314. doi: 10.1007/s10734-004-6386-5

Moreno-Ruiz, L., Castellanos-Nieves, D., Braileanu, B. P., González-González, E. J., Sánchez-De La Rosa, J. L., Groenwald, C. L. O., & González-González, C. S. (2019). Combining flipped classroom, project-based learning, and formative assessment strategies in engineering studies. *International Journal of Engineering Education*, 35(6), 1673-1683.

Nayak, A. S., Hiremath, N. D., Umadevi, F. M., & Garagad, V. G. (2021). A hands-on approach in teaching computer organization & architecture through project based learning. *Journal of Engineering Education Transformations*, 34, 742-746.

Nisan, N., & Schocken, S. (2005). The Elements of Computing Systems. Cambridge, MA: MIT Press.

Shahin, M., Ali Babar, M., & Zhu, L. (2017). Continuous Integration, Delivery and Deployment: A Systematic Review on Approaches, Tools, Challenges and Practices. *IEEE Access*, 5, 3909-3943. doi: 10.1109/ACCESS.2017.2685629

Shute, V. J. (2008). Focus on Formative Feedback. *Review of Educational Research*, 78(1), 153-189. doi: 10.3102/0034654307313795

Soares, L. P., Achurra, P., & Orfali, F. (2016). A hands-on approach for an integrated engineering education. Proceedings of the PAEE/ALE'2016, 8th International Symposium on Project Approaches in Engineering Education (PAEE) and 14th Active Learning in Engineering Education Workshop (ALE), Guimarães, Portugal, 294-302.

Soares, L.P., & Ferrão, R.C. (2018). Continuous Integrated Team Learning. Proceedings of the PAEE/ALE'2018, 10th International Symposium on Project Approaches in Engineering Education (PAEE) and 15th Active Learning in Engineering Education Workshop (ALE), 202-209. http://paeeale.unb.br/_upload/PAEE_ALE_2018_proceedings.pdf

Spertus, E., & Kurmas, Z. (2021). Mastery-based learning in undergraduate computer architecture. In 2021 ACM/IEEE Workshop on Computer Architecture Education (WCAE) (pp. 1-7). IEEE.

Taras, M. (2005). Assessment – Summative and Formative – Some Theoretical Reflections, *British Journal of Educational Studies*, 53:4, 466-478. doi: 10.1111/j.1467-8527.2005.00307.x

Villamañe, M., Álvarez, A., & Larrañaga, M. (2020). CASA: An Architecture to Support Complex Assessment Scenarios. IEEE Access, 8, 14195-14206. doi: 10.1109/ACCESS.2020.2966595

Winning the European Cyber Security Challenge 2022: What did We Learn?

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Abstract

The European Cyber Security Challenge is organised every year by the The European Union Agency for Cybersecurity (ENISA) with the aim of making more young people interested in cyber security and encourage young people to pursue an education and career within the field, thus helping to mitigate the shortage of cyber security skills. Denmark has participated in the competition since 2017, but especially since 2021 invested significantly in the national competition, leading to the creation of a significant youth community.

In 2022, the Danish team won the European Cyber Security Challenge among 28 European countries and 5 guest countries. In this paper we describe the efforts behind the scenes, and the work done from the beginning with public and beginner-friendly virtual training sessions all the way until the selection and training of the final national team of 10 talents. We discuss the learning points and take-away messages, which we believe can be valuable for everyone working with talent development and recruitment within technology and engineering.

The first part of the paper describes how the Danish Cyber Security championships were organised throughout winter and spring of 2022, and how lot of effort was invested in attracting new young people to the field through a series of online training sessions. The competition itself – in 3 stages - was based on solving practical challenges in an easy-to-access gamified environment, where we encouraged the students to learn from each other after each part of the competition. The second part of the paper discusses the training of the national team in more detail, with particular focus on soft skills and team building.

In conclusion, our experiences demonstrate how it is possible to attract more young people to cyber security through awareness, active learning, gamification, and community building. Finally, we discuss some of the challenges we still must address – including diversity.

Keywords: Active Learning; Engineering Education; Gamification; Community Building; Cyber Security.

1 Introduction

With our societies becoming increasingly more digitised, we also become more vulnerable to cyber attacks. According to Center for Cyber Security, which is a part of the Danish Defense Intelligence Services, the cyber threat against Denmark is considered to be "very high", both in terms of cyber espionage by other states and economically motivated crime, mainly carried out by well organised criminal groups (Center for Cyber Security, 2022). There is also a high threat from cyber activists, where the activity has increased dramatically since Russia invaded Ukraine in February 2022. In addition to specific cyber-attacks against individuals, companies and authorities, there are also politically motivated actors who are trying to impact democratic decisions and elections, e.g. through disinformation campaigns or strategical use of information – the most famous examples probably being the attack on the US election in 2016 (Jamieson, 2019) and the Cambridge Analytica case (Schneble, Elger & Shaw, 2018). To counter the cyber risk, many countries are implementing new legislations, such as the Network and Information Security Directive 2 (NIS2) in the European Union.

However, one of the biggest challenges in cyber security – and one that is not solved by new legislation being put in place – is the lack of cyber security professionals. (ISC2, 2022) estimates that the current skill gap on a global scale is 3,4 mio. people. At the same time, there is also a lack of skilled people in IT in general, so there is no easy fix as to recruiting these people from related fields. Therefore, there is a strong need for attracting more young people to choose an education and career within cyber security.

At the same time, the field of cyber security has been quite successful in using gamification both within education programmes and on publicly available platforms such as TryHackMe (TryHackeMe, 2023) and HackTheBox (HackTheBox, 2023). In an effort to attract more young people to cyber security, Aalborg University has also made a beginner training platform called Haaukins (Panum et al., 2019), which based on the Capture The Flag (CTF) concept (Collins & Ford, 2023) allows participants to try out hacking in a safe and secure environment that is accessible through a web browser – with an automatised platform behind, which makes it possible for e.g. teachers to setup specific trainings for their students with just a few clicks.

One large-scale project that is also based on gamification and CTF is the European Cyber Security Challenge (ECSC) (ECSC, 2023), which is every year organised by the European Network and Information Security Agency (ENISA) together with a local hosting country. This is considered the official European Championship in Cyber Security, and also due to its sports/competition-like approach, it gains a high level of visibility in the participating countries. The main event takes place during September or October and is a 2-day competition where each country participates with a team of up to 10 participants aged 14-25, of which at least 5 should be 14-20 (juniors). There is no requirement as to have a minimum number of participants aged 21-25 (seniors), but usually there would be 5 juniors and 5 seniors. Denmark has participated in ECSC since 2017, but since 2021 the Danish participation was boosted thanks to a grant from the Danish Industry Foundation. This made it possible to not only create a single competition in order to select a national team, but a series of trainings and competitions that would constitute the Danish Cyber Security Championships. In this paper, we will explain how we have done this, and our experiences and learning points. We are of course pleased that Denmark won the European competition in 2023, but the most important is that we have engaged a lot of young people in Cyber Security.

The rest of the paper is organised as follows. After this introduction, the next section presents the first part of the trainings and competitions, which led to the selection of the national team for ECSC, and the experiences and learning points. The following section then presents the training of the national team for the competition, including experiences and learning points from that part. With this in place, we summarize the learning points in the conclusion, and discuss how we can use the championships to become even better in attracting more young people to work with cyber security in the future.

The Danish Cyber Security Championships are held in collaboration between five Danish universities, with Aalborg University having the lead role, The Danish Defense Intelligence Services, which is a public authority, as well as the private company Happy42 which has specialised in hackathons and talent development within IT and technology. The challenges and training sessions are delivered by the universities, and developed by more than 30 student helpers, PhD students and university professors. In this way, the project also supports building cyber security communities at the universities.

2 The Danish Cyber Security Championships

The competition of the Danish Cyber Security Championships was conducted in three stages of competition. However, before the competition itself a number of virtual training sessions are held, and the final competition leads to the selection of 25 possible participants for the national team, which are then finally selected during a bootcamp, as illustrated by Figure 1. This section describes the training sessions, the three stages of competition, and the bootcamp. As a general overview, the different elements were timed like this:

- February 17 – March 16: Virtual training sessions.
- February 26 – March 20: Virtual qualification round (Qualifiers).
- April 9: Regional Championships (Regionals).
- May 7: National Championships (Nationals).
- June 10-12: Bootcamp.

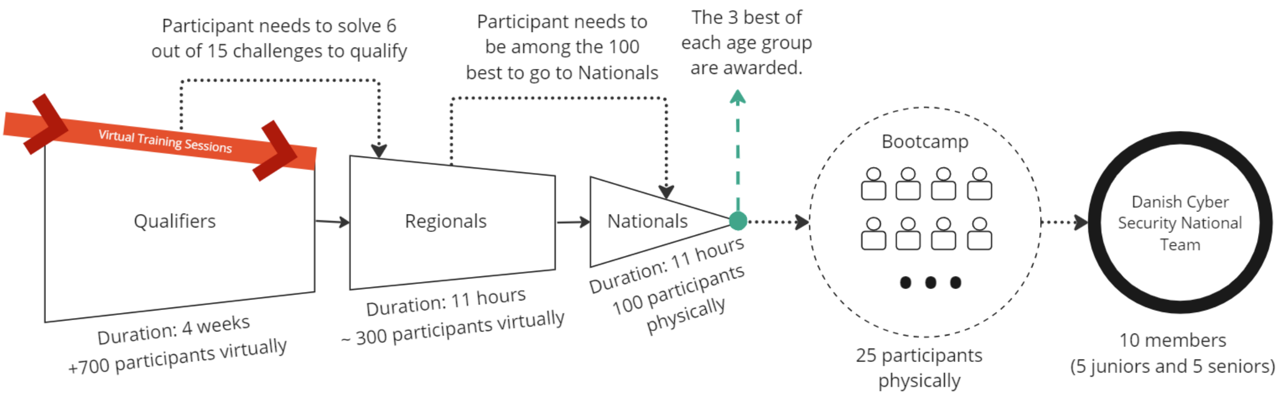

Figure 1. The process of The Danish Cyber Security Championships as it was in 2022.

When describing the different elements, we also try to address two key challenges in the project – challenges, which we expect only to become more outspoken in the coming years if we succeed with scaling the competition and getting more young people interested in cyber security:

- The main purpose of the project is to attract and engage more young people in cyber security. This requires us to design a beginner friendly competition, where nobody feel lost. At the same time, the competition is a flagship competition where the best can win a prestigious seat on the national team. Therefore, the best participants expect to be challenged all the way through the competition.
- Similarly, we want to create a fun and engaging competition for participants at all levels. Yet, at the same time the competition is also the foundation for selection the national team. In order to select a strong national team, it is important to let those with deep specialist competences shine, whereas for beginners we want to more easy challenges to get some good experiences.

While the competition is largely based on events in the competition flow, we maintain both a website and a Discord server. The Discord server is used for communication related to the competitions including technical support, but also supports the community building among participants both before, during and after the competition flow. This is important also in order to sustain the community between competitions, and to maintain the interest in cyber security of the participants.

2.1 Virtual training sessions

The virtual training sessions are a crucial part of the Danish Cyber Security Championships. The concept was first used for the championships in 2021, where they were initially thought to be physical training sessions, but then held virtually due to the Coronavirus situation. However, the experience with the virtual format was positive, and it allows participants from all over the country to follow the training sessions, so we decided to go with this format again. The virtual format is also good in the setting of participants with very diverse backgrounds, since everything can be broken into smaller micro modules (2-4 hours), which allows those who need it to study and practice between modules.

A total of 26 modules were offered mainly for beginners, and centred around the different categories of the competition, so that it should be possible for everyone who followed the training sessions also to solve the first stage of the competition – the virtual qualification. Some were stand-alone topics, other topics consisted of 2-3 sessions with a clear progression between them. Usually, the sessions were held on afternoons or evenings using Zoom. The participants could see a short description of all the training sessions offered on championship website, and sign up on beforehand.

We attracted a total of 1.800 participants, but since some participated in more than one training session, we estimate the number of unique participants to be around 1.000.

In 2021, the experience was that we "lost" many of the participants between training and competition due to all the training sessions being carried out before the first stage of the competition started. For this reason, we changed the schedule to give some overlap between training sessions and competition, so we could encourage the participants to solve challenges of the virtual qualification round right after each training session. Moreover, the training sessions were done also with the qualifier challenges in mind, so the participants could use their new skills in the competition itself.

The learning points from the virtual training sessions were:

- The sessions were generally well received by the participants.
- It worked particularly well when there is a good mix between theory and practical exercises.
- It was clear that the participants had themselves chosen to attend the sessions, so everyone participated with a high degree of engagement, and the sessions were often also discussed in the Discord channel afterwards.
- With so many trainings at different levels, it becomes hard for the participants to maintain an overview of what is relevant and what fits the level of the individual. Therefore, in the future we should think of creating more structured learning paths, without scaring away new participants by overloading them by options.

2.2 Virtual qualification round

The virtual qualification round consists of 15 challenges, of which each participant has to solve 6 to qualify for the Regional Championships (Regionals) and thus remain in the competition. There is no limit as to how many participants can qualify for the Regionals. Most of the challenges are the same for junior and senior participants, but we made a small differentiation with 3 easier challenges for juniors, and 3 more difficult for the seniors. This also reflects that the level can be very different among these two age groups. Participants sign up on our website, where they can also access the challenges - all challenges are available during the whole qualification, so each participant just has to solve 6 challenges before the qualification ends in order to receive an invitation letter for the Regionals. Everything is handled in the CTFd portal (CTFd, 2023), which means that when a participant solves a challenge he/she receives a code of text known as a flag – e.g. "DDC{this_is_a_flag}" – which can then be entered into the portal, and the points are registered for the participant. The categories are the same for all stages of the competition: Forensics, Binary Exploitation, Cryptography, Reverse engineering, Boot2Root, Web exploitation and Misc. The challenges are very diverse but could for example be to analyse the data from a computer that was hit by ransomware (forensics), to decrypt an encrypted message (cryptography), or to find and exploit vulnerabilities on a website (web exploitation).

It is not allowed for participants to help each other or to discuss the challenges. However, once each stage of the competition is over it is allowed to exchange writeups and discuss the challenges.

One particular consideration for the challenge design has been that we want it to be possible to qualify both for participants who are experts within a single category, and those who have a broader skillset. For example, a specialist in cryptography can be a very valuable asset on the national team, even without having much knowledge in any other discipline, and as such we want to ensure that this person can qualify. Since we would not have the resources to create 6 challenges in each category, this implies that some challenges should be possible to solve with limited prerequisites.

Another consideration regards the tooling and access to challenges. Many of the more experienced participants will have their own technical setup (i.e. a virtual machine with various hacker tools). However, this is a barrier for the newer participants. For this reason, we provide everyone with access to a virtual machine through their own browser, which can again be used to access other virtual machines with challenges, so no special software is required. The drawback is that the more experienced participants experience a poorer performance than if using their own machines, and that only the tools selected by us are available. This again puts restrictions on the challenges, since everything should be solvable with the tools we provide.

A total of 720 persons participated in the qualification round, of which 310 qualified for the Regionals.

We noted the following learning points:

- Overall, the virtual qualification worked well. We were happy with the number of persons participating, but we also note that less than 50% solved the required 6 challenges. Moreover, the number of girls decreased from 13% in the trainings to 4% in the qualification.
- Some of the more experienced participants found that the technical setup (i.e. the web based virtual machines) was annoying for them. They would like the possibility to use their own virtual machines to access the challenges.
- Some of the more experienced participants found the qualifiers to be "very easy", which is natural given the nature of the competition. It could be considered to do something additional for this group, as long as it does not scare away some of the beginners.
- Allowing for writeups and challenge discussions works well and give rise to many good interactions where participants learn from each other. It should be considered to release official writeups for all challenges in a more structured manner, to support the learning even more.

2.3 Regional Championships

Denmark is administratively divided into five regions, and the Regionals are organised accordingly. This means that in principle it is five separate competitions, and that participants compete with each other within the regions. However, the competitions are all based on the same challenges, and takes place at the same time. To allow as many as possible to participate, Regionals are organised as a fully virtual competition using the Zoom platform: First everyone is welcomed in a joint room across regions, then participants are sent to breakout rooms for each region with a local competition leader, and when the time is up the results are announced in a joint room again. To also help building communities and connections between participants, we arrange four physical meetups, where it is possible to sit together (but not work together) and socialise during the day with food, drinks, etc. provided by us. The competition takes place over a full day, 10.00-20.00, and there are around 40 challenges across the different categories. In addition to finding the Senior champion and Junior champion in each region, the competition also serves as a qualification for the National Championships (Nationals), where the following qualifies:

- Top 5 in each age category in each region.
- Top 25 overall in each region (those already qualified are removed from the list before this selection).

The latter balances the selection when some regions have many more participants than others. However, when in some regions the number of participants in one of the age categories is lower than 5 (or just a few more), some of the participants will be able to gain some easy seats for the Nationals. Our estimate is that around 3-5 of those who qualified for Nationals would not have done so if they competed in other regions.

We had 289 participants signing up to the Regionals, competing for the 100 seats for Nationals.

The learning points from the Regionals are related to some of the points and considerations already discussed:

In general, the challenges were good, but there was a lack of beginner friendly challenges – in fact, around 10-15% of the participants did not solve a single challenge during the day. Being an online competition, we do not know for sure if all participants were active during the whole day, but for most it is not encouraging to spend a whole day without any success. For 2023, we therefore decided to create a specific "beginner track" of challenges that would contain steps/tutorials/hints, and where it would be allowed for the support team to give hints to the participants which is otherwise a no-go. By giving very few points for these challenges, it will not have a big impact on the competition, and we avoid promoting a participant strategy where solving many easy challenges will give more points than solving a few expert level challenges.

An important point also discussed for qualifiers was whether participants should use their own virtual machines and tools. For the regionals, we decided to give the participants the choice of using the in-browser option or their own virtual machine with their own tools. However, it was decided to still apply a policy that all challenges should be solvable in either way. This does not go without drawbacks, since it excludes otherwise good challenge ideas, which in reality would be approached only by expert level participants.

Another point is the scoring mechanism used, i.e. how many points participants receive for a certain challenge. There are two principles that can be used, Static Scoring where a challenge is designated a number of points, or Dynamic Scoring, where the number of points depend on how many participants have solved it (given some parameters, including maximum and minimum number of points, and how many solves to reach the minimum). In order to make points comparable across regions, we decided this year to go with the static scoring. However, we also found that it is difficult to decide on the number of points in a fair way – especially across categories when it comes to difficult challenges. Also, some challenges might have easier solutions than they were designed for, potentially making the number of points way off. Problems with awarding the correct number of points can lead to experts in some categories being significantly favoured over experts in others and can potentially lead to strong players not proceeding to the Nationals. The experience with static scoring led us to decide for using dynamic scoring for the Nationals, being well aware that with static scoring the number and level of challenges within the different categories is still very important: For example, many challenges in one category will lead to fewer solves per challenge and thus more points.

2.4 National Championship

The National Championship is a physical event, where the 100 participants who qualified compete during a full day (10.00-22.00). Being a physical event, it is also a flagship when it comes to creating visibility about cyber security in general and the championships in particular. This is supported by also having a line-up of speakers and special guests participating in challenges. For example, in 2022 the Danish minister of Defense Morten Bødskov participated and was part of one of the challenges: This included him reading some text from the stage which was necessary in order to solve that particular challenge.

Based on the experiences from Regionals, dynamic scoring was used, which worked well and was well received by the participants.

The 25 participants from bootcamp were selected based on the results from Nationals. The selection was based on a combination of total scores (i.e. rankings) and demonstration of special competences. For example, a participant with expert skills in crypto could be selected even without being among the top 12-13 participants in his/her age group.

Most of the learning points from the Nationals have been listed already under qualifiers and regionals. One point worth highlighting is the value of such a physical event, also for the community building and networking among the young talents. Becoming a flagship competition on the other hand also means that the participants have high requirements in terms of quality of challenges and infrastructure.

2.5 Bootcamp

The bootcamp is arranged in collaboration between the university partners and the Danish Defense Intelligence Services. It runs from Friday evening and finishes Sunday early afternoon. The bootcamp incorporates elements such as:

- Team building.
- Technical trainings.
- Technical challenges to be solved in groups (group CTF).
- Participants being exposed to challenges in new/unfamiliar categories.

The purpose of the bootcamp is two-fold: First of all, to give the participants an amazing experience together, which will help them gaining friends among other young people interested in cyber security, and second to give the trainers a good background for selecting the final national team of 10. As such, the bootcamp allows for observing how the participants are performing when it comes to person skills, collaboration, team work and communication, but also how they approach new and unseen challenges and work under pressure. Based on these observations, the final team is selected. Since it is very prestigious to be selected for the national team, and some of the participants are willing to go far in order to get there, we take good care in making the bootcamp environment safe, respectful, and welcoming. Arranging the bootcamp together with the Danish Defense makes it possible to give the participants some unique experiences, that also demonstrate that their skills – and themselves – are important for our society.

We had three females participating in the national competition, of which two made it to the bootcamp. Only one made it to the national team. This clearly demonstrates the need for working systematically with increasing diversity in the field: We really need more females to enter the competition flow in order to end up with more females also on the national team.

Otherwise, the most important learning point from bootcamp is that we always need to find the right balance between the technical content, which is why the participants are there, and the team building aspects including physical activities which can give unique experiences and good observation points for selecting the national team.

2.6 Participant evaluations

Surveys were distributed at two stages: A survey to everyone who participated in the Regionals competition, but who did not qualify for the Nationals, and those who participated in the Nationals. However, the number of respondents were limited, especially for the former case (32 respondents from the Regionals, and 38 from the Nationals).

From the Regionals, 63% of the respondents had previously participated in cyber security activities. Most agreed that their participation had increased their knowledge in cyber security (63% agree very much, 31%

agree a little), and all found that their participation had increased their interest in cyber security (59% agree very much, 41% agree a little). 63% very much agree and 28% agree a little that they will continue to cultivate their interest in cyber security. In general, the participants were happy with the difficulty level of the competition, with most finding the qualifier challenges easy/adequate, and the regionals challenges adequate/difficult. The difficulty level of the regionals might have been a little too high, since 13% found the challenges to be "way too difficult".

From the Nationals, 66% of the respondents had previously participated in cyber security activities. Most agreed that their participation had increased their knowledge in cyber security (76% agree very much, 18% agree a little), and most found that their participation had increased their interest in cyber security (68% agree very much, 29% agree a little). 84% very much agree and 13% agree a little that they will continue to cultivate their interest in cyber security. In general, the participants were happy with the difficulty level of the competition, with most finding the qualifier challenges easy, and the regionals challenges adequate/difficult. Among those who qualified to Regionals, only 5% found that the regionals challenges were "way too difficult". For the Nationals competition, 50% found the difficulty level to be adequate and 50% found them difficult. None of the respondents found the challenges "easy", "way too easy" or "way too difficult".

As a final remark on the evaluations, the physical event of the Nationals competition was highly appreciated.

3 Training the National Team

The National Team consists of the 10 final participants selected through the competition flow described in the previous section. While the 10 team members are all highly skilled and talented, it is also a very diverse group, potentially with a very wide age range (15-25 years old), different skill sets and expertise levels, and different levels of experience with cyber security and CTF competitions. The training, which takes place from when the team is selected mid-June and until ECSC which in 2022 was held mid-September is based on the following considerations:

- Until and including the bootcamp in June, the members have been competing against each other for a place on the national team. Once the team is formed, this competition is over, and focus is to build a team based on mutual trust and collaboration.
- To work well as a team, it is also important to know the competence areas of the different members and to expand on competences if there are any areas that are not fully covered, despite of the selection process.
- Practice for the test: The team needs to play a lot of competitions together, in order to benefit from being a team and not just 10 individuals dividing all tasks between them.

The training is mainly carried out by three trainers in collaboration: A university professor in cyber security, a PhD student within cryptography with significant CTF experience, and an IT security consultant with a background in the Danish Defense (and originator of the Danish National Cyber Security Team).

The training was generally organised as a one-day meetup and three official training weekends. In fact, another (unofficial) weekend training was added since there was a suitable competition. In addition, the teams played several CTF competitions together, they trained and learned individually, and we tried to organise trainings within "competence clusters" also throughout the three months.

The initial meetup day was focused on teambuilding, e.g. escape rooms, and on forming the "competence clusters". The idea behind the competence clusters was that there should be at least three team members with a high level of competences within each of the competition categories. This ensures that the team members have sparring partners when they are working on the challenges, and it gives flexibility when e.g. an expert team member in one field is busy. It also facilities that the team members learn together, which is especially useful since it requires a very high amount of resources to improve individual team members skills.

During the weekends, the different focus points and activities included:

- Competition training: As a team, it is important to play a lot of competitions together to get the routine in working together and to gain good habits, such as: Starting out well getting a good overview of the challenges, having the right strategy on how to select which challenges to prioritize and start with, daring to ask questions and offer help when needed, etc. This was done by systematically evaluating important aspects of each "trial competition", decide on focus points for the next time, and refresh these focus points before playing together again.
- Training team roles: By ECSC rules, each team is required to have a Team Captain who is responsible for all formal communication with the competition organisers. In our team, we expanded this role with a First Mate who is helping the captain keeping track of what different team members are doing and prioritising tasks/resources, and a First Engineer who is overall responsible for the infrastructure the team is using. For these roles to work well under pressure in competition, it is also crucial to train and discuss the roles thoroughly on beforehand.
- Practicing attack-defense: ECSC 2022 was organised as two competition days, each with a different competition. Day 1 was CTF, where each team should solve challenges and gain as many points as possible, whereas Day 2 was an attack-defense competition where each team gets a set of (vulnerable) IT services and have to defend and patch their own systems while at the same time attacking the other teams. While all team members had experience with the CTF format, the attack-defense format for many was a new discipline, and with few open competitions that the team could join. So it was a priority to setup an infrastructure to be able to first do a competition within the Danish team (split into 3 sub-teams), and then a full trial competition where the team could play as a whole team against other countries (for which we invited some of the other Nordic countries).

One aspect that carries through the activities is to build a team that trusts and help each other: Where it is expected that you ask for help when you are stuck, and equally expected to offer help if approaches or if you think it could be relevant – and to have a joint understanding on the team that this is necessary to perform well as a team.

We feel that the national team training was working well, and that the focus points paid off in the final competition where the Danish team won both the CTF and the attack-defense part. One reflection is that we found it hard to provide expert level technical training: Since every team member has a different profile this would almost need to be on an individual basis, and thus require both time and the right training resources. But maybe we should draw more upon the initial experiences with virtual trainings for beginners and try to deliver more expert level technical training to the growing number of young talents (not only those on the national team).

4 Conclusion

When Denmark won the European Cyber Security Challenge in 2022, it was the first small country to do so. While this was achieved by the national team alone, we do believe that the efforts invested in building a strong cyber security community among young people are also paying off. Despite the small size of the country more than 700 young people participated in the initial qualification round: And the larger a talent pool that is attracted to cyber security, the better the chances to also establish a strong national team. To continue building these communities, it is now of utmost importance to continue the efforts of talent development – not only among the 10 who made it to the national team, but also among the many that participated in virtual trainings and/or the first stage(s) of the competition: These might be on a future national team, but even more importantly can they contribute to closing the cyber security skills gap, which is one of the most critical issues to address for our societies to become more digitally secure.

Both ECSC and the Danish Cyber Security Championships demonstrate that gamification and competitions are useful when it comes to attracting talent to cyber security, especially when supplemented with relevant training sessions and a beginner friendly approach. The evaluations also indicate that the competitions attract new people to cyber security, and that the participants find that the competition increases both their interest and their knowledge in cyber security. However, the experiences also demonstrate some challenges to be addressed, such as:

- Development of training sessions, which reflect the diversity in participants backgrounds, and which makes it easy to choose a relevant learning path for each participant – also tackling the risk of participants being overloaded with information and options.
- Development of a competition flow and setup that is friendly and easy to join for newcomers to cyber security, but at the same time provides experienced participants – with expert level knowledge – a fair and high-quality competition that they also can learn from. This includes a well thought through challenge composition, choosing appropriate scoring mechanisms, and creating a technical setup that is easily accessible for beginners.
- Attracting more females to cyber security and the competitions described in this paper. In particular, the experiences from this paper demonstrated how a small number of females in the training sessions became an even smaller number in the competition itself.

While CTFs are a good match for cyber security, we believe that the conclusions are also useful for other fields of engineering education: CTFs have been around for a long time, but the integration with community building activities, online training sessions, and the recognition that follows the involvement of industry and authorities, is creating a strong environment around the competition, and helps to both attract and retain the talent.

5 References

Center for Cyber Security (2022). The Cyber Threat Against Denmark, https://www.cfcs.dk/en/cybertruslen/threat-assessments/the-cyber-threat-against-denmark/.

Collins, J & Ford, V. Teaching by Practice: Shaping Secure Coding Mentalities through Cybersecurity CTFs. Journal of Cybersecurity Education, Research & Practice. Vol. 2022, No. 2 (2022). DOI 10.32727/8.2023.8.

CTFd (2023). CTFd website, https://ctfd.io.

ECSC (2023). Website of the European Cyber Security Challenge, https://ecsc.eu.

HackTheBox (2023). HackTheBox website, https://hackthebox.com.

ISC2 (2022). (ISC)2 Cybersecurity Workforce Study, https://www.isc2.org/-/media/ISC2/Research/2022-WorkForce-Study/ISC2-Cybersecurity-Workforce-Study.ashx.

Jamieson, K. H. (2019). How russian hackers and trolls exploited U.S. media in 2016 1. Proceedings of the American Philosophical Society, 163(2), 122-135. Retrieved from https://www.proquest.com/scholarly-journals/how-russian-hackers-trolls-exploited-u-s-media/docview/2394545430/se-2.

Panum, Thomas & Hageman, Kaspar & Pedersen, Jens & Hansen, Rene. (2019). Haaukins: A Highly Accessible and Automated Virtualization Platform for Security Education. 236-238. 10.1109/ICALT.2019.00073.

Schneble, Christophe & Elger, Bernice & Shaw, David. (2018). The Cambridge Analytica affair and Internet-mediated research. EMBO reports. 19. 10.15252/embr.201846579.

Tryhackme (2023). TryHackMe website, https://tryhackme.com.

Lessons learned from an international cross-disciplinary engineering collaboration: a case study of the Educado project

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Abstract

Since 2018, the "SDG Challenge", collaboration between Aalborg University (AAU) and the University of Brasilia (UnB), includes the project Educado, a platform designed to provide education and information for waste pickers, a group of workers who lack access to such resources. This project originated due to the shutdown of the largest dump site in Latin America in 2018, shifting the traditional income source for the waste pickers to a structured recycling cooperative system. In this multifaceted project, the ambition is helping the former waste pickers improve their quality of life, by enhancing their current work conditions and providing resources for further education. This paper presents the reflections and lessons learned from over four years of collaboration, focused on the challenges encountered and the solutions developed. Educado is a complex and unique collaboration between students from: Production Engineering, Product and Design Psychology, Cyber, Software, and Computer Engineering. Additionally, the project was run by a student-driven company named "SomethingNew" between 2020 and 2023. This paper discusses issues identified within the project, including the need to adjust for new students every semester, and carrying over conclusions between student groups. Secondly, managing an excess of teams working on the project, and difficulties in communication between teachers, supervisors, and students especially during the COVID-19 pandemic. Finally, general lessons learned within the collaboration are discussed. The main contribution of this paper is a framework of recommendations and methodologies for international cross-disciplinary engineering collaborations between universities, based on the experiences acquired. The lessons learned from this case study provide guidance for future collaborations and highlight the importance of collaboration, communication, and adaptability in achieving successful outcomes in cross-disciplinary engineering projects.

Keywords: Engineering Education; International Collaboration; SDG Challenge; Multi-disciplinary;

1 Background

The "SDG Challenge", partnership led by Aalborg University (AAU) and the University of Brasilia (UnB), was initiated to develop practical solutions to real-world problems related to the Sustainable Development Goals, following United Nations (2015). One of the projects launched by the SDG Challenge in 2018 is Educado, a platform designed to provide education and information for waste pickers who lack access to such resources. This project came about following the closure of the largest dump site in Latin America, which, according to Campos (2018), caused a shift in the traditional income source for waste pickers to a structured recycling cooperative system. Educado's objective is to enhance the quality of life of former waste pickers by improving their access to information and providing access to further education.

The Educado project is a multifaceted collaboration involving students from different engineering disciplines such as Production Engineering, Product and Design Psychology, Cyber, Software, and Computer Engineering. The project was also managed by a student-driven company called "SomethingNew" between 2020 and 2023. The processes involved in managing this collaboration and development over the years (see Image 1), with different people and dynamics involved, resulted in a valuable case in PBL education, as it, following principles stated by Jørgensen, U., & Kolmos, A. (2017), is a project and collaboration designed to provide students with the skills and knowledge to address complex, real-world problems.

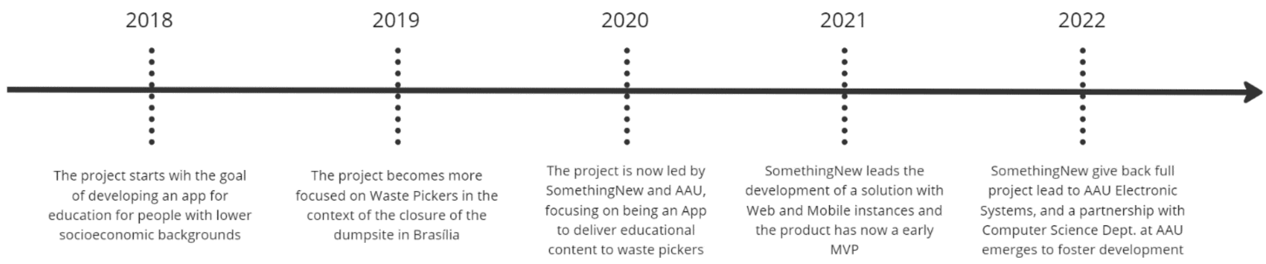

Image 1. The summarized timeline of the Educado Project over the years.

Smith et al. (2018) argue that international collaborations in engineering education can result in successful outcomes by adhering to effective collaboration, communication, and adaptability practices. This paper presents the reflections and lessons learned from over four years of collaboration on the Educado project. It discusses the challenges faced during the project, including team turnover and communication difficulties experienced during the COVID-19 pandemic. Additionally, it offers a framework of recommendations and methodologies for international cross-disciplinary engineering collaborations between universities based on the experiences acquired.

According to Alhouti et al. (2021), in cross-disciplinary engineering projects, particularly when aiming for product development, successful outcomes rely significantly on the implementation of effective collaboration, communication, and adaptability practices. The significance of this paper is to emphasize the importance of good practices regarding these aspects in achieving successful outcomes in cross-disciplinary engineering projects, especially when aiming at product development. This study provides valuable guidance for future collaborations and emphasizes the need for continuous efforts to address sustainable development challenges.

2 Collaboration Methodology

The methodology used for collaboration in the Educado project is discussed before highlighting the challenges, lessons learned and framework for future collaboration. The SDG Challenge projects are conducted in cycles of one semester, composed by three main phases (see image 2): (i) SDG Challenge event (SDGe), in which we plan and kick-off the projects; (ii) onboarding, in which we mobilize students in the different universities, within the participating courses, to develop the projects during the semester; and (iii) the Semester Projects themselves, in which the scopes defined in the SDGe are executed by the teams recruited in the phase (ii). After phase (iii) of one given SDG Challenge cycle, the flow goes to phase (i) again, but of the following cycle.

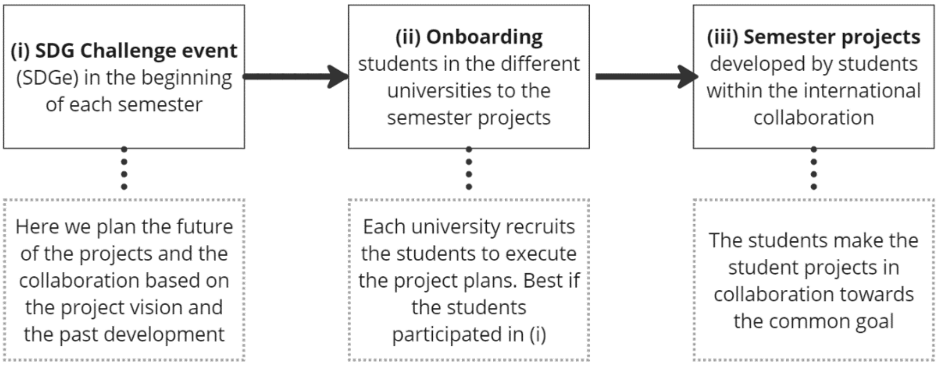

Image 2. The general view of a cycle of projects in the SDG Challenge.

The following methodological description and analysis will concentrate in the phase (iii) of Educado, which is the collaboration and development per se – although all the phases are approached. We break this section in high-level cross-university collaboration, low-level student group collaboration, and internal policies used by both AAU and UnB.

2.1 High level collaboration

In the context of collaborative work among professors involved in the project and partnership, the main mode of communication was through occasional meetings scheduled among the involved parties, in addition to emails and instant messages. However, for the purpose of establishing common procedures and connections between different project teams, voluntary students played a key role as intermediaries. While physical meetings between teachers and students would occur during the annual SDG Challenge event (SDGe) in Brasilia – which takes place in the beginning of each semester cycle - there was no defined framework for coordination during the semester. Therefore, the collaboration primarily relied on ad-hoc communication channels and the voluntary efforts of students to facilitate effective collaboration.

2.2 Low Level Collaboration

Throughout the Educado project, student-to-student collaboration has taken various forms, driven by both the need for diverse knowledge-sharing and practical factors such as the number of students involved in the project during a particular semester from both universities. Consequently, the collaboration between students can be classified into two main categories: paired student groups and mixed student groups.

Paired student groups comprise students from both universities who have a direct link with each other. To foster interdisciplinary collaboration, these groups usually comprise students from different fields, rather than those with identical backgrounds. For example, a computer engineering group from AAU may be paired with a Production Engineering group from UnB. These groups combine and broaden the perspectives of the project, using their different specializations.

In some semesters, direct pairing is not possible due to differences in student numbers or other factors such as groups reforming or combining. To manage such uneven teams, the methodology is to have mixed student groups, in which the different teams continued working on established grounds and building on previous conclusions but avoiding overloading groups with many collaboration partners. Although mixed student groups have a more limited collaboration aspect than paired student groups, they still utilize different aspects of the Educado project using previous student projects, enabling groups to work more independently.

In summary, the paired student groups are teams that actively collaborate with other teams during the semester; and the mixed student groups are teams that are also involved in the common theme and goal of developing the Educado product, but that do not collaborate or have very limited collaboration over the semester.

2.3 Internal Policies

With the collaboration methodologies described, the internal policies for onboarding students to the project, and the level of autonomy given to each student group is discussed for both AAU and UnB.

2.3.1 UnB

Within the context of the SDG Challenge, Educado was developed at the University of Brasilia (UnB) in Brazil as part of the Production Systems Project (PSPs) courses. The project scope was presented to the students mainly by the teachers or by some volunteer students, accompanied by short description documents. The SDG Challenge website played a role in some phases of the project for onboarding new students. However, students executing the semester work were not necessarily the ones who participated in the initial planning event (during the SDGe), which caused some disconnection between the plan and execution, as discussed in the next sections of the paper. At University of Brasília, the students have in general little to no decision power of which project they will take in the semester, as the professor is the one who has the final word, making it easier to guarantee that there will be teams to execute a certain scope, but potentially decreasing the affinity students have with the scope, since the scope might be not of high interest to certain students. During the project, students had a considerable amount of freedom in decision-making, and collaboration was considered substantially decentralized.

2.3.2 AAU

At AAU, the collaboration structure placed a significant amount of responsibility on the students for the success of their projects – with substantial independency of decisions and planning. This is the case since the before the beginning of the project, because the students have the final word of which scope, they will execute in their projects. As a result, there is a flatter power structure, with a lot of autonomy given to the students to decide the paths of the project and the depth of their engagement in the collaboration.

In the case of Educado, besides the development of the product and the solution for the waste pickers' situation, the goal of the project is to encourage students to develop their skills on independent collaboration continually, which is supported by both the supervisors and SomethingNew.

This autonomous approach also means student groups that participate in Educado, join specifically due to a desire to be part of the project, and the project proposals are usually spread via word of mouth or through a supervisor suggesting it within a project presentation round. More formal project proposals have not been made for the Educado project, due to the limited amount resources available for AAU and SomethingNew to help support the projects.

The students from the departments of Computer Engineering, Cybersecurity, and Product and Design Psychology all fall under the umbrella of the Electronic Systems department at AAU. This organizational structure simplifies the onboarding process for new students, as many of the methodologies and supervisors are shared between these subjects.

However, the software engineering course involved - i.e. "Software 5" (SW5) - is part of a different department, requiring the collaboration structure to be a bit more complex to match the different procedures and requirements even in the collaboration within AAU. Particularly, in the SW5 course the students do not have autonomy to decide the project they will execute during the semester, as the entire course is dedicated to the Educado App. This also increases the supervision and project support required, having SomethingNew supporting the teams, as well as a Product Owner from Electronic Systems with knowledge of the problem and product.

3 Challenges & Lessons Learned

Over the course of the years of collaboration, the team has encountered various challenges, and through their efforts, have gained valuable insights and lessons learned. In this section, we will discuss the challenges faced during the project and the corresponding solutions developed.

3.1 Remote collaboration

The Educado project has always relied on remote collaboration due to the involvement of students from different countries and continents. While the project managed to progress, the collaboration was not always consistent, and some parts of the project suffered from infrequent communication, possibly due to time zone differences, busy schedules, and focus on the respective specific parts of their projects. However, it was observed that collaboration was more consistent when the students had previously met in person and participated in the physical SDG Challenge event (SDGe). The opportunity to build personal relationships and establish a sense of teamwork through physical interaction proved to be invaluable in maintaining a consistent level of collaboration.

In turn, the COVID-19 pandemic had a significant impact on the project. While the full transition to online meetings made communication easier and allowed for more flexibility in scheduling, it was more difficult to conduct co-working sessions, as the physical space is often more appropriate for this type of collaboration. However, the project benefited from the increased ease of international collaboration due to the shift towards online work. Nevertheless, the pandemic made it more difficult to understand the problems fully, as it was not possible to visit stakeholders and relevant problem locations. Consequently, the team had to find alternative methods of information gathering and testing solutions. Finally, the relationship between the different individuals involved in the project was different as they are typically facilitated through physical interaction. Despite these challenges, this period in the Educado project demonstrated the importance of adaptability and effective communication in achieving successful outcomes in cross-disciplinary engineering projects, with an important goal of having students meet physically at the start of their semester projects as shown in *Image 2*.

3.2 Mixing methodologies

Establishing common high-level methodologies proposed a larger challenge, due to the interdisciplinary nature of the project. A main objective for a higher-level methodology is to enable the students from all different fields to excel in their speciality, whilst creating a common thread throughout. A large factor in a successful implementation is aligning the factuality / supervisors before the beginning project, and most importantly the flexibility of supervisors to modify existing methodologies internal to either field or university to better fit a global collaboration. In this way, the Problem Based Learning (PBL) proved to be a good starting point, as with a common understanding of the problem space, nuances more specific to different fields could be solved within said fields and requirements for a successful implementation easily translated between the different fields.

However, some challenges persist such as ensuring a common understanding also between students, especially ensuring that conclusions drawn in previous semesters by previous students are not lost. To overcome this challenge, the idea of a shared library with both the reports and a project summary including most important lessons are being made.

It should also be noted that whilst knowledge sharing around methodologies specific to a field, e.g., computer engineering is encouraged, by limiting the methodology mixing to a higher level, the different universities are also able to teach closer to their specific methodologies, simplified the collaboration significantly.

3.3 Project Distribution/ Complexity

It should be noted that at a certain point during the project's development in Brazil, an excessive number of student projects were initiated. This was due to the teachers having complete control over assigning students to projects and becoming enthusiastic about certain projects without the underlying infrastructure to facilitate such rapid growth in participation, resulting in an overabundance of students being involved. As a result, the team working on the Educado project found itself with an over-dimensioned team. This created complexity and made it challenging to manage and define cohesive scopes for each team, as well as ensure that all team outputs were well-coordinated. This hurdle is best solved by creating clearer project scale plans and coordinating better on a higher level as described in Section 2.2.1.

3.4 Property Rights

Since the Educado project involves a diverse group of students with different backgrounds and expertise, the issue of property rights to the platform is important. Given the mixed background of students contributing different aspects to the project, determining ownership can be challenging. However, to ensure the project's success in helping waste-pickers and helping the students feel motivated and taking ownership of their contributions, it was chosen that the property rights structure must grant ownership to everyone involved.

As the project's end-product is a software-based solution, open-sourcing the project is the simplest methodology for addressing property rights. By adopting an open-source approach, all involved parties have full access to the code and can use it for any future project. This open approach to property rights aligns with the Educado platform's non-profit nature, which relies on student projects as main contributions.

During SomethingNew's management of the project, the code remained available to anyone wishing to access it, however without a public-facing code repository. The next step for the project is to complete the open-sourcing process and ensure public availability. For software-based projects like Educado, this approach is highly recommended as it encourages students to contribute and feel ownership of their contributions, a big source of inspiration and motivation for students.

3.5 Project Management

As discussed in section 3.3, the project faced challenges in management and coordination due to the over dimensioned group of teams and students involved. In addition to this, there were communication issues arising from the different platforms used for communication and task management by each team, and the lack of a formal way to hold meetings between all the different teams. These teams were also enrolled in different courses with varying requirements, making it difficult to reconcile these requirements with the project's needs. This required volunteer students to act as intermediaries between the project and the teachers' requirements.

Another challenge was the decentralized power and management structure with no one exclusively dedicated to the project consolidation. Therefore, it was difficult to define cohesive scopes for each team and ensure that all outputs were well coordinated. To mitigate these challenges, it would have been helpful to have a product owner from the beginning of the project and a team responsible for the development and design of the solution.

3.6 Learning From Past Mistakes

The conception of the Educado project started almost five years ago in 2018, and its future success is based on the ability to learn from past mistakes and evolve the project.

Concrete examples of problems found within the project are (i) scoping the project too broadly, making it confusing for future student groups to join the project by including too many aspects and future potential growth plans, and (ii) focusing too far on the future, neglecting current next steps due to an ingrown understanding not translated to newer students.

These issues, among others, have arisen through the project development, and while the goal is not to commit errors, it is sensible to think many errors have been made, and the point is to focus on identifying and improving on past mistakes.

This requires an open mind from all the faculty and students to continuously improve. This understanding that learning and improving is imperative in creating a long-standing successful collaboration is also one of the main subjects that lead to the creation of this paper, with the goal of presenting the projects challenges and the solutions found.

For example, the scope creep issue has been solved by re-scoping the project to only revolve around the waste-pickers and the problems facing them here-and-now. Because only once the here and now are solved, is it sensible to expand the scope the future help and learning.

3.7 Knowledge Management

One of the most important lessons learned during the collaboration was related to knowledge management. The various teams worked on different semesters and courses, producing a range of outputs that were locally managed by each course. As discussed in topic 3.5, the lack of a central person to consolidate the project resulted in a chaotic collection and management of the outputs, which had several consequences. For example, it was not uncommon for teams taking over the project in subsequent semesters to have no contact with some of the previous outputs and starting development from scratch, without benchmarking against prior solutions. Additionally, at the current stage of the project, it remains uncertain if all the outputs from different teams have been collected. This approach generates waste in the development flow, with some team efforts being ignored, and rework often necessary. A possible solution to this issue is to assign a dedicated person to manage the project and maintain a structured digital repository for the different outputs of the project, to ensure a unique place for consolidation.

4 Framework for Structured Collaboration

The framework of collaboration consists in a set of prioritized aspects and good practices that were important to the achievement of the results seen within the Educado project. More importantly, this framework also presents the challenges the project has faced and the solutions that have been found to this issue-set. With this framework of challenges faced and the solutions found within the Educado project, the goal is for this framework to be useful for future international, multidisciplinary, engineering PBL based projects:

Table 1. Risks and Points of attention and the subsequent adequate solutions.

Risks and points of attention	Adequate solutions identified
Unstructured and infrequent communication due to time zone differences, busy schedules, and focus on the respective specific parts of their projects.	Establish a standard communication flow, defining, from the beginning of the project, (i) the communication channels and applications; (ii) dates for recurring general meetings with all teams during the semester. Involve the professors in the meetings to increase engagement and send calendar invites via email.
Crashing methodologies between different courses and universities	Implement from the beginning of the project a culture of flexibility, adaptability and conflict resolution, explicitly talking about this in a first meeting with all the people involved in the collaboration. Moreover, make constraints clear from the beginning, including course requirements, availability of the teams and project development methods. Manage this in the recurring general meetings with all teams during the semester.
Lack of alignment between different professors/supervisors involved	Establish a Steering Group composed by all the supervisors involved and make a recurring meeting to ensure frequent discussion of the collaboration
Excessively decentralized power and management structure	Assigning a student responsible (Product/Project Owner) with at least one year position to consolidate the project is essential. This person can be a volunteer but must be rewarded with extension credits or other valuable monetary or academic returns. The period of one year ensures at least two semesters under the management of this person. Besides consolidating results, this person should also be responsible for the cohesive vision of the process and leading the teams towards it.
Excessive number of student groups involved, resulting in an over-dimensioned team and lack of cohesive scopes; difficulty in management and coordination	Ensure, in the period of project planning before the start of the semester, that the Product/Project Owner agrees with the need to involve any given number of teams from each course. He/She should be responsible for assessing the usefulness of the team, which will be important not only to ensure the result but also for the relevance of the experience for the students.
Unclear or potentially conflicting property rights over products	Open sourcing the project and product, and being clear about it since the beginning, is recommended to grant ownership to everyone involved and minimize complexity and conflicts related to unknown product ownership.
Knowledge waste, rework and teams unnecessarily starting from scratch	Establish a unique location for consolidation of files over time. This needs to be defined since the early stages of the very beginning of each project. Appointing an exclusive individual to oversee the undertaking and sustain the organized digital repository for the various products of the project is also important. Make the location/repository available for all the teams from the beginning of their involvement.

When planning a large multidisciplinary inter-university collaboration like the Educado project, a checklist based on the findings of the Educado project should be considered:

(i) Establishing structured means and frequency of communications.

(ii) Establishing methodologies limitations and making methodologies complementary.

(iii) Creating a steering group of all relevant supervisors.

(iv) Assigning student product owners, especially after the first semester of a project.

(v) Agree on a feasible scale where all students can contribute and feel like they have a meaningful impact on the project.

(vi) Specify the ownership of each student and supervisors' contributions.

(vii) Create a structured methodology for knowledge sharing and retention, ensuring the project continuously moves forward.

Lastly, it has also been observed that for projects that extend over multiple semesters, it is crucial to appoint a student responsible for each project. This will ensure consistent vision, management, and knowledge consolidation. For the SDG challenge, which involves multiple projects in the Educado format, we recommend the establishment of a project management office. Each project/product owner will be enrolled in this office to ensure an effective project leading. The University of Brasilia is currently working towards setting up this project management office.

5 Conclusion

To summarize, the paper presented the collaboration methodologies, reflections and lessons acquired from the Educado project, which is part of the "SDG Challenge" collaboration between Aalborg University (AAU) and the University of Brasilia (UnB) over a four-year period. The project aimed to provide education and resources to waste pickers who were affected by the shutdown of Latin America's largest dump site. The project involved students from different fields such as Production Engineering, Product and Design Psychology, Cyber, Software, and Computer Engineering. Various challenges were identified during the project, such as adapting to new students each semester, managing multiple teams, and communication difficulties between teams, especially during the COVID-19 pandemic. The paper offers a framework of recommendations and methodologies for cross-disciplinary engineering collaborations between universities, based on the project experiences. The study highlights the significance of collaboration, communication, and adaptability for successful outcomes in cross-disciplinary engineering projects. The findings provide guidance for future collaborations in this area.

6 Reflection & Future Work

As a reflection on the Educado project, the partnership between Aalborg University and the University of Brasilia has been impactful and fruitful and, therefore, will continue. Moving forward, the aim is to further develop the platform to a point of full implementation with the waste pickers. To achieve this, the project will be conducted with the Product Owner in the Project Management Office established at UnB, considering the business model and financial sustainability of the solution.

Regarding future collaboration models, the framework presented in this paper will serve as a guide. The focus will be on establishing a common vision and ensuring cohesion in the development process, while also involving stakeholders in the phases of development. This approach will ensure that the project remains lean and selects scopes that maximize the benefits of the project by evolving the essential features of the product for sustainable long-term success.

It is worth noting that the international cross-disciplinary collaboration will continue in a strong Problem-Based Learning (PBL) based model, with a focus on the experience of the students and the real-world impact of the project.

7 References

Alhouti, S., Al-Tabtabaei, S., Al-Weshah, R., & Al-Weshah, S. (2021). Factors influencing the success of interdisciplinary engineering projects in higher education. Engineering, Technology & Applied Science Research, 11(2), 7175-7179. doi: 10.48084/etasr.4076

Campos, H. K. T. (2018). Como fechamos o segundo maior lixão do mundo. Revista Brasileira de Planejamento e Orçamento, v. 8, n. 2, p. 204–253.

Jørgensen, U., & Kolmos, A. (2017). PBL in Engineering Education: International Perspectives on Curriculum Change. Aalborg University Press.

Smith, K. A., Sheppard, S. D., Johnson, D. W., & Johnson, R. T. (2018). Pedagogies of engagement in science and engineering. John Wiley & Sons.

United Nations. (2015). Transforming our world: the 2030 Agenda for Sustainable Development. Retrieved from https://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E

Innovations in Engineering Teaching Observatory: preliminary results about a Brazilian State

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Abstract

Innovation in engineering education has become a relevant goal for teachers, researchers, and professionals specialising in Engineering Education around the world. In this context, the adoption of active learning strategies (ALS) has been considered because of its benefits. This scenario motivated the study presented in this paper which aims to make a preliminary identification of the adoption of ALS in engineering programs at public institutions in the state of Minas Gerais, Brazil. Out of the 219 Engineering programs offered by public institutions in Minas Gerais, according to the e-MEC platform, 8 institutions presented a relevant position because they mention a considerable quantity of ALS terms in their curriculum planning. An analysis of the pedagogical projects of engineering programs offered by these institutions was made, using the same keywords mentioned by the Active Learning Working Group in Engineering Education, a precursor research group that has relevant work in Brazil. The prominent institutions and the number of keywords mentioned by them were: Federal University of Itajubá (392), Federal Institute of Education, Science and Technology of Minas Gerais (136), Federal University of Uberlândia (110), Federal Institute of Education, Science and Technology of the South of Minas Gerais (103), State University of Minas Gerais (94), Federal University of Ouro Preto (78) and Federal Center for Technological Education of Minas Gerais (70). The most frequent keywords were Games; Interdisciplinary Project; Problem or Project based Learning (PBL); Integrator Project; Active Methodology; Active Learning; Flipped Classroom and Project-Based Learning. Future steps of this research will identify how these practices are used, with the purpose of confirming the evidence raised in this preliminary study. It is one of the following steps of this research that has the support of the Research Supporting Foundation of Minas Gerais State.

Keywords: Active Learning Strategies; Engineering Education; Innovation in Engineering Education.

1 Introduction

The adoption of active learning strategies (ALS) in the context of engineering education has been widely discussed in recent decades. Several studies point to the effectiveness of ALS in several situations (Caldeira *et al*, 2022) and there are authors that consider Active Learning and Engineering Education are a natural match (Pinto *et al*, 2020). This is due to the external imperatives of a changing society and even because of the profile of the generation Z student (born from 1998 to 2009). These aspects have brought stimuli to the search for new teaching and learning strategies.

In Brazil, the National Curriculum Guidelines of Undergraduate Engineering programs, established by the National Council of Education, through Resolution CNE/CES No. 2, of April 24, 2019 (MEC, 2019) are aligned to the need of more effective teaching strategies. Following this regulatory framework, engineering education institutions can use ALS to create a more critical, reflective, creative and cooperative training. Yet, it is assumed that ALS can favour a holistic, humanistic and ethical vision in the students. These guidelines demand that the engineer's training include the development of technical skills and, above all, the encouragement of transversal skills (MEC, 2019).

In order to identify how these guidelines are used in practice, this paper presents the preliminary results of an investigation to understand the teaching-learning practices of engineering programs in public institutions in the state of Minas Gerais, Brazil. The present work is one of the first steps of a greater project whose objective is the creation of an observatory of pedagogical practices that are considered innovative. This research project is financed by the Research Support Foundation of the State of Minas Gerais (FAPEMIG).

This research has been done at 19 institutions within the scope of the study. According to the e-MEC platform, in Minas Gerais, engineering programs are offered at the following public institutions: State University of Minas Gerais (UEMG), State University of Montes Claros (UNIMONTES), Federal University of Alfenas (UNIFAL), Federal University of Itajubá (UNIFEI), Federal University of Juiz de Fora (UFJF), Federal University of Lavras (UFLA), Federal University of Minas Gerais (UFMG), Federal University of Ouro Preto (UFOP), Federal University of São João Del Rey (UFSJ), Federal University of Uberlândia (UFU), Federal University of Viçosa (UFV), Federal University of Triângulo Mineiro (UFTM), Federal University of the Jequitinhonha and Mucuri Valleys (UFVJM), Federal Institute of Minas Gerais (IFMG), Federal Institute of Northern Minas Gerais (IFNMG), Federal Institute of Southern Minas Gerais (IF SUL DE MINAS), Federal Institute of Southeast Minas Gerais (IFSEMG), Federal Institute of Triângulo Mineiro (IFTM) and Federal Center of Technological Education of Minas Gerais (CEFET).

In this paper, the following research question was posed: What are the evidences of adoption of ALS in public institutions of higher education in engineering programs, in the state of Minas Gerais, Brazil, based on the analysis of their PPPs? For this, a preliminary analysis of the pedagogical projects of the 219 engineering programs offered by public institutions in the state of Minas Gerais, according to the e-MEC platform, will be presented. Through this analysis, it was possible to classify the institutions in terms of evidences of ALS use. Furthermore, the results show the most mentioned terms referring to the use of ALS.

In the next sections, some reflections on practices and discourses present in the planning process of engineering programs in Brazil will be presented. Afterwards, the methodology used in the study, data analysis and possible discussions for the answer to the research question are presented.

2 Active Learning and Teaching Planning in Engineering Education - practices or discourses?

In the context of Brazilian higher education, Bazani & Miranda (2018) and Gil (2018) present the planning process at four levels, from macro to micro: educational, institutional, curricular and teaching. All these planning processes, in an articulated way, lead to what happens in class (Izeki, 2022). Based on this framework, it is possible to discuss how active learning is mentioned at each level of planning, putting into discussion the difficulty of transposing the discourse and identifying the adoption of ALS as a practice.

At the level of educational planning, in engineering programs, the planning process starts from the National Curriculum Guidelines (NCG). This regulation presents a set of precepts for the implementation and execution of higher education programs, determined by the Higher Education Chamber of the National Education Council. The responsibility for regulating this level is federal and is subordinated to the National Education Policy, which is formulated by the Ministry of Education (Gil, 2018). In 2019, the latest version of the NCG was published, to which engineering programs had to adapt when conceiving, among other novelties, competency-based teaching (MEC, 2019). Thus, the NCG determines that engineering programs offer learning activities that ensure the development of competences, established in the graduate profile. Furthermore, the NCG determines that the use of methodologies for active learning must be encouraged, as a way to promote a more student-centered education.

At the institutional planning level, the Institutional Development Plan (IDP) is prepared. As required by the Ministry of Education, each Higher Education Institution must disclose its work philosophy, pedagogical guidelines, organisational and physical structure. In this document, the higher education institution must present the faculty profile and academic activities it intends to develop (Sant'Ana *et al.*, 2017). In this planning process, will be established the institutional guidelines that will be considered in the following planning level.

At the so-called curriculum planning level, based on the NCG, prepared in the educational level and the IDP, elaborated at the institutional level, the pedagogical project of the program (PPP) is elaborated or updated by a group of professors that is called Structuring Teaching Nucleus which is responsible for designing, consolidating and continuously updating the PPP, being responsible for ensuring compliance with the NCG (MEC, 2010). The PPP is a document that must contain an analysis of the context in which the program is offered and the characteristics of the graduate profile. In addition, the PPP must explain the elements that make up the teaching-learning experiences. This document presents the curricular matrix as well as the units that make up the curriculum of the programs. As Francelino & Salgado (2022) argue, among engineering programs there is still a predominance of technical thinking, which increases the challenge of allowing curriculum planning to dialogue with the precepts of active learning advocated by the NCG.

To complete the planning process of engineering programs in Brazil, it is necessary to talk about teaching planning. At this level, the teacher of each course prepares the plans that will be used with the students (Bazani & Miranda, 2018). At this level, the professor will define the general methodology to be used in the course the content to be shared, the resources to be used, and the evaluation procedures. As it is the micro level of planning, it is expected that this step is aligned with the previous levels of planning, being an instrument of educational action and not a mere bureaucratic step (Izeki, 2022).

To achieve a real transposition from the discourse into the practice of adopting ALS, a new teaching planning process is necessary, which requires a new role from the instructor. The professor will no longer position her/himself as an expert in a given subject. He or she will act as a pedagogical mediator, partner of the student in the construction of their knowledge and professional practices. The professor will be the planner of learning situations in their classes, which may happen in different environments (Masetto, 2018). In teaching planning, the teacher will be able to select among the ALS that best collaborate with students to achieve the proposed objectives (Masetto, 2018).

In this context, when ALS is adopted as a practice, several benefits of using them for the teaching and learning processes are evidenced in the literature (Caldeira *et al.*, 2022). The following effects of active learning can be mentioned: reduction of school dropout (Guedes et al., 2014), development of transversal skills (Pereira; Pinto & Campos, 2018a), increased motivation to study before class (Pereira; Pinto & Campos, 2018b), increased student engagement (Nagai & Izeki, 2016), contribution to Calculus learning (Cuzzuol *et al.*, 2018) and development of scientific writing skills (Santos, 2018).

3 Methodology

The question that guided this research was: What are the evidences of adoption of ALS in public institutions of higher education in engineering programs, in the state of Minas Gerais, Brazil, based on the analysis of their PPPs? The objective was to identify evidences of the adoption of ALS in engineering programs by analysing the main product of the curriculum planning process. This study was characterised as exploratory research

(Marconi & Lakatos, 1990) based on documentary investigation. As a source of information, public archive documents of written origin were considered, these being the PPPs of engineering programs offered by public institutions in the state of Minas Gerais, accredited by the Ministry of Education. Such sources were extracted from the official pages of the universities.

In order to identify the institutions that were the focus of the research, a search was carried out in the e-MEC/ Ministry of Education system, a platform created with the purpose of facilitating the process of accreditation and re-accreditation, authorization and recognition of Higher Education Institutions (MEC, 2023). Through this initial survey, a total of 19 universities or federal institutes and 219 programs offered in Minas Gerais were found. From the definition of the institutions included in the research, a search was carried out on the official pages of the participating higher education institutions in order to have access to the PPPs.

Out of the 219 undergraduate engineering programs offered at higher education institutions in the state of Minas Gerais, it was possible to download 202 PPPs.

Considering the downloaded documents, a categorization and analysis of the PPPs was carried out in order to investigate the mention of keywords referring to some ALS. For the analysis of results, document content analysis was used (Sá-Silva et al., 2009). The keywords used for the PPPs analysis followed the same parameters used by Pinto *et al.* (2020), when they carried out a systematic mapping on the adoption of ALS in the papers published in the Brazilian Congress of Engineering Education (COBENGE) from 2007 to 2019. In this study, the authors elected 45 terms referring to ALS pointed out in the literature as relevant terms in the context of engineering education.

When carrying out the scans in the surveyed PPPs, it was possible to list the institutions that used the terms referring to the adoption of ALS. In addition, it was possible to identify the terms referring to ALS most used in the institutions under analysis. These data were used to identify the status of ALS adoption in the curriculum planning process of public engineering institutions in the State of Minas Gerais, Brazil.

4 Data analysis

After analysing the 202 available PPPs, it was possible to identify the institutions that mention terms referring to ALS in their curriculum planning level. Figure 1 shows the institutions whose PPPs were analysed and the number of times terms referring to ALS were mentioned.

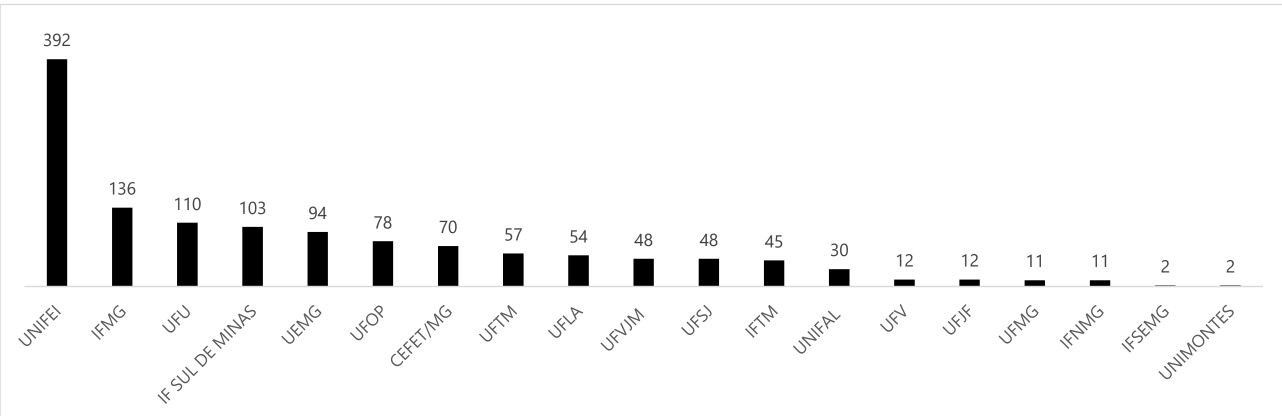

Figure 1. Institutions and the number of mentions of terms referring to ALS mentioned in the PPPs.

It is worth highlighting the 7 institutions (UNIFEI, IFMG, UFU, IF SUL DE MINAS, UEMG, UFOP and CEFET/MG) with the highest number of terms mentioned, since these institutions together correspond to 75% of the mentions of ALS found in PPPs. From these data, it is possible to infer that, in these institutions, ALS are known and were considered in the writing of PPPs of their engineering programs.

The most frequent keywords and their number of appearances are presented in Table 1.

Table 1. Terms referring to ALS mentioned in the PPPs.

Terms referring to ALS	Quantity
Game(s)	432
Interdisciplinary projects	260
PBL	204
Integrator Project	68
Active Methodology	53
Active Learning	47
Flipped Classroom	43
Problem based learning (in Portuguese)	42
Project based learning (in Portuguese)	33
Design Thinking	29
CDIO	25
Problem Based Learning	15
Project Based Learning	15
ABP	13
Collaborative learning	7
Cooperative learning	6
Other terms	23
Total	1315

The terms interdisciplinary project and PBL (second and third positions in this analysis) were also among the most cited terms in Pinto *et al.* (2020). Project-based learning appears among the most cited by 4 terms (PBL, project-based learning, integrative project and interdisciplinary project), which corresponds to 44% of the analysed mentions. This reinforces the importance of projects as a pedagogical tool in engineering teaching (Caldeira *et al.*, 2022).

Evidently, in order to identify how these practices are used, it is necessary to use other investigation methods to confirm the evidence raised in this preliminary study. Thus, it is necessary to determine how this level of curriculum planning is deployed in practices at the level of teaching planning.

5 Conclusion

According to the analysed data, the following institutions deserve to be mentioned: UNIFEI, IFMG, UFU, IF SUL DE MINAS, UEMG, UFOP and CEFET/MG. These institutions together correspond to 75% of mentions of ALS found in PPPs. It should also be noticed that the institutions IFSEMG and UNIMONTES were the ones that least mentioned ALS terms. It is worth noticing that, as it is a preliminary survey based on the PPPs, this analysis will be supplemented by other investigations in future phases of this research.

Content analyses will also be carried out on the documents raised, in order to identify how these strategies are used. Other considerations will be made due to the difference in size and structure of the institutions. Also, on-site surveys will be carried out to validate the data collected and to verify how ALS are adopted in these institutions, at the teaching planning level.

Responding to the research question, it is possible to state that evidence of the use of ALS was found in higher engineering education institutions in Minas Gerais. There is great variability in the number of mentions of the terms, making it possible to infer that there is a group of institutions where the practice of active learning is more frequent at the level of curriculum planning (UNIFEI, IFMG, UFU, IF SUL DE MINAS, UEMG, UFOP and CEFET/MG). The low number of terms used in the other institutions raises the hypothesis that the guidelines related to active learning have not yet been considered in the PPPs that were analysed.

Given the exposed data, it is clear that even though it is a preliminary investigation, the objectives were achieved through official data mining. This investigation was essential to elucidate the next steps of the research in the search for the creation of the Observatory of Innovation in the Teaching of Engineering of the State of Minas Gerais, funded by the Research Support Foundation of the State of Minas Gerais (FAPEMIG).

6 References

Bazani, C. L., & Miranda, A. B. de. (2018). Planejamento no ensino superior. In G. J. Miranda, E. A. Leal, & S. P. de C. C. Nova (Eds.), Revolucionando a docência universitária - Orientações, experiências e teorias para a prática docente em negócios (1st ed.). São Paulo: Atlas.

Caldeira, B. C., Campos, L. B. P., Souza, I. A. M. de, Oliveira, D. J. de, Nagai, W. A., Morais, A. de A., … Santos, R. dos. (2022). Programa de capacitação docente em aprendizagem ativa nos cursos de engenharia: o relato de experiência da Universidade Federal de Itajubá - campus Theodomiro Carneiro Santiago. In O. Mattasoglio Neto, R. dos Santos, A. E. B. Marques, F. Oliveira, J. A. G. Baesso, T. B. Dumet, & T. S. da Silva (Eds.), Boas práticas de formação docente em Engenharia (pp. 83–101). Brasília: ABENGE.

Cuzzuol, G. D., Campos, L. B. P., Mesquita, D., & Lima, R. M. (2018). Engineering Students can use the words 'calculus' and 'love' in the same sentence: using active learning the impossible can happen. In International Symposium on Project Approaches in Engineering Education (pp. 273–281).

Francelino, J. M., & Salgado, T. D. M. (2022). Diretrizes Curriculares Nacionais, Projeto Pedagógico e Metodologia PBL: Uma Análise de suas Conexões no Ensino de Engenharia. *Revista de Ensino de Engenharia,* 41, 203–214.

Gil, A. C. (2018). Didática do Ensino Superior (2nd ed.). São Paulo: Atlas.

Gil, A. C. (2020). Metodologia do Ensino Superior (5th ed.). São Paulo: Atlas.

Guedes, F. C., Campos, L. B. P., & Braga, R. A. da S. (2014). Actions on First Term Disciplines Aiming to Decrease Dropout Rate of the Computer Engineering Course. In V. Villas-Boas & O. Giovannini (Eds.), Problem Based Learning in Engineering Education (pp. 158–169). Caxias do Sul: ABENGE.

Izeki, C. A. (2022). Planificação Docente no Ensino Superior: *Um Estudo numa Universidade Brasileira na Disciplina de Programação Introdutória*. [Tese de doutoramento, Universidade do Minho]. https://hdl.handle.net/1822/78763

Marconi, M. de A., & Lakatos, E. M. (1990). Técnicas de pesquisa. São Paulo: Atlas.

Masetto, M. T. (2018). Metodologias Ativas no Ensino Superior: Para Além da sua Aplicação, Quando Fazem a Diferença na Formação de Profissionais? Revista E-Curriculum, 16(3), 650.

MEC. (2010). Resolução n. 1, de 17 de junho de 2010 - *Normatiza o Núcleo Docente Estruturante e dá outras providências.* Http://Portal.Mec.Gov.Br/Index.Php?Option=com_docman&view=download&alias=6885-Resolucao1-2010-Conae&category_slug=outubro-2010-Pdf&Itemid=30192.

MEC. (2019). Resolução n. 2, de 24 de abril de 2019 - *Institui as Diretrizes Curriculares Nacionais do Curso de Graduação em Engenharia.* Http://Portal.Mec.Gov.Br/Index.Php?Option=com_docman&view=download&alias=112681-Rces002-19&category_slug=abril-2019-Pdf&Itemid=30192.
MEC. (2023). e-MEC - *Cadastro Nacional de Cursos e Instituições de Educação Superior*. Https://Emec.Mec.Gov.Br/.
Nagai, W., & Izeki, C. (2016). As estratégias de gamificação da disciplina de Projeto e Análise de Algoritmos segundo o Modelo Dinâmico de Aprendizado baseado em Jogos (p. 1159). Retrieved from https://doi.org/10.5753/cbie.wcbie.2016.1159
Pereira, L. B., Pinto, J. A., & Campos, R. J. (2018). Entrepreneurial Education and Project Based Learning (PBL): Outcomes in Engineering. Journal of Modern Education Review, 8(11), 844–855.
Pereira, L. B.; Pinto, J. A.; Campos, R. J. (2018b, February 28-March 01-02) *Teaching Economics to Engineering Students: results of a flipped classroom experience.* [Paper presentation]. PAEE/ALE'2018: International Symposium on project approaches in engineering Education - Active Learning in Engineering Education Workshop, Brasília, DF, Brasil.
Pinto, G. R. P. R., Oliveira, J. A. C. B., Viana, D. M., Neves, R. das, & Villas-Boas, V. (2020). Work-in-Progress: A Systematic Mapping Study of Experiences with Active Learning Strategies and Methods in Brazilian Engineering Education. In 2020 IEEE Global Engineering Education Conference (EDUCON) (pp. 1819–1823). Porto.
Sant'Ana, T. D., Bermejo, P. H. de S., Mendonça, L. C., Santos, N. de M., Borges, G. H. A., Souza, W. V. B. de, … Melo, G. S. (2017). Plano de desenvolvimento institucional - PDI: um guia de conhecimentos para as instituições federais de ensino. Alfenas: FORPDI.
Santos, R. dos. (2018). Significant and Autonomous Learning of Scientific Writing by Active Methodologies in Portuguese Language classes. In 2018 3rd International Conference of the Portuguese Society for Engineering Education (CISPEE) (pp. 1–7). IEEE. Retrieved from https://doi.org/10.1109/CISPEE.2018.8593492
Sá-Silva, J. R., Almeida, C. D. de, & Guindani, J. F. (2009). Pesquisa documental: pistas teóricas e metodológicas. Revista Brasileira de História & Ciências Sociais, 1(1), 1–15.

Emotional Education in Engineering Education: a hands-on experience

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Abstract

Emotional difficulties have been reported by students in many higher education contexts. In Brazil, according to the National Forum of Deans of Student Affairs, 80% of the students have some emotional difficulty related to money scarcity, high academic workload, inability to organise study routine and difficulty to adapt to new situations. It can be said that, in an Engineering student's context, this situation is the same. Engineering students are always under pressure because of good academic results and many academic and personal duties, without appropriate tools to deal with the emotional roller-coaster called academic life. Emotional education is aligned to many actual imperatives but it is still out of the curriculum and, sometimes misunderstood and seen as an unimportant issue to students and professors. In this context, this paper aims to show an initiative that was held at Federal University of Itajubá – Itabira campus as a possible strategy to include emotional education in this institution. An 8 hour workshop was offered to the university community with the objective to let participants go into a journey of self-awareness, emotional alphabetization, group dynamics and a self-assessment questionnaire designed to permit the participants to evaluate their various competences of emotional intelligence. 18 people took part in the workshop and it was available at the university website and was viewed 50 times. Emotional intelligence is an important factor for the processes of integration and academic affiliation, which corroborates to the improvement of indicators for university management (reduction of evasion and retention, among others). This workshop is in line with the actions to improve institutional performance and improve academic and social processes.

Keywords: Emotional Education; Engineering Education; Emotional Intelligence.

1 Introduction

The human dimension of engineering education has been emphasised worldwide. Some movements such as the Bologna Convention proposing a learning-centered education around Europe and even the Brazilian Curricular Guidelines to Engineering Programs are some examples of an attempt to adapt the learning process to fast-changing labour market which demands a holistic approach in the context of engineering education (Vipin, Panicker & Sridharan, 2012).

In this circumstance, the discussion addresses a new paradigm of teaching-learning that has placed the student at the center of education. In this context, it is important to affirm that education must encompass the various dimensions of the student, such as physical, emotional, intellectual and spiritual dimensions of the individual (Vipin, Panicker & Sridharan, 2012). Considering the changing and competitive society, where the demand for future graduates is in constant reformulation, it is critical to help students to recognize and to develop their socio-emotional dimension (Casado, López & Lapuerta, 2016).

This analysis becomes even more challenging considering the prevalence of common mental disorder (CMD) among higher education students (Lopes et al, 2022). CMD are a group of signs of somatic and emotional symptoms that include: insomnia, fatigue, physical malaise, irritability, sadness, nervousness, anxiety, stress, forgetfulness, difficulty concentrating and feeling worthless. Considering national and international literature, it is possible to indicate that the academic routine makes students vulnerable to the development of some mental disorders such as depression, anxiety and stress (Lopes et al, 2022; FONAPRACE, 2019).

Considering all this context, some initiatives have been executed in order to promote emotional education to students. It is assumed that socio-emotional skills must be included in the engineering curriculum (Chisholm, 2010). Despite that, in Brazil, emotional education is still out of the curriculum and, sometimes misunderstood and seen as an unimportant issue to students and professors.
This paper aims to show an initiative that was held at Federal University of Itajubá – Itabira campus as a possible strategy to include emotional education in this Engineering institution. An 8-hour workshop was offered to the university community with the objective to let participants go into a journey of self-awareness, emotional alphabetization, group dynamics and a self-assessment questionnaire designed to permit the participants to evaluate their various competences of emotional intelligence. 18 people took part in the workshop and it was available at the university website and was viewed 50 times.

2 Emotional Education in Engineering Education Context

Emotional Education is the process by which children and adults learn to understand and manage emotions, and regulate emotion and behaviour. Its final aim is to give learners the competencies that are considered the basic building blocks of effective adaptation and function in everyday life (Zysberg & Le, 2018). In order to investigate the adoption of emotional education in the context of Engineering Education, the authors of this paper made a literature search. From a search in the Web of Science database of publications with the terms "emotional education" and "engineering education" in the abstract, it was possible to perceive the expansion of this international literature recently (Figure 1). It shows that the interest in emotional education in the context of engineering education has been growing in recent years, but is still restricted to fill a dozen of papers published annually.

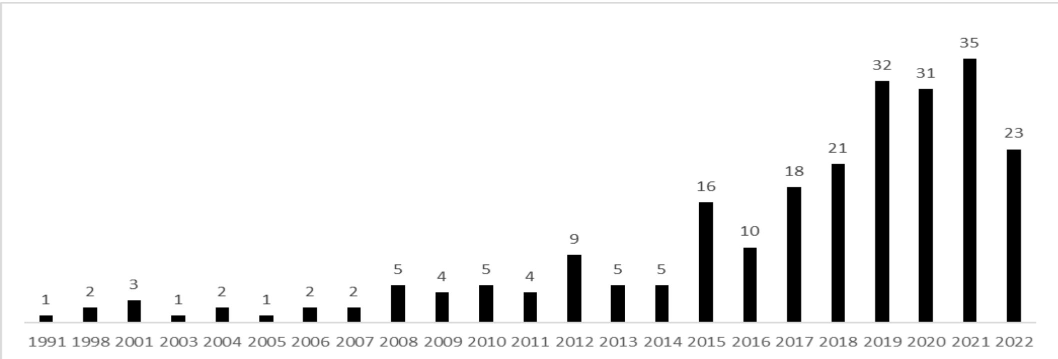

Figure 1: Web of Science publication from 1991 to 2022 with research key-words “emotional education” and “engineering education”

Analysing some of these papers, it is possible to notice an effort that is spread worldwide to introduce some emotional educational experience to engineering students. There are initiatives that were organised in some subjects and that were planned by a professor in order to increase the emotional competences of the students. Reimer (2001) reported an experience in a course in computational visualistics at the Otto-van-Guericke University, in Magdeburg, Germany, set out to blend technical aspects with perspectives from the humanities. Reflection was combined with the traditional technical computer science to cover computer game design. The process of reflection was embraced by the students and contributed to the emotional development of the students through the process of regulation and utilisation of emotion to become more self-aware, creative and motivated (Reimer, 2001).

There are experiences that took place in the level of an engineering program. Experiences that were offered not only to a class but to all the students of a program. This kind of initiative was organised by the School of Computing Engineering of the Costa Rica Institute of Technology (TEC). The initiative was a multidisciplinary project that was called "Experiencia 360º" (Arroyo-Herrera *et al*, 2019). Aligned to the university strategy to promote soft skills development to students, a Project Management course was chosen as a propitious context to execute the "360° Experience" project. In this experience, emotional education was offered as several related skills were stimulated such as negotiation, communication, leadership, problem solving and conflict management.

In a wider way of executing the emotional education, Casado, López & Lapuerta, (2016) report a project consisting of several educational innovation projects carried out at the Technical University of Madrid (UPM). The aim of this work was to improve the socioemotional competencies of its students and professors. In this experience, several training techniques such as online, blended and face-to-face seminars, and coaching processes were used. 451 students and 135 professors from six engineering schools of the UPM enrolled in the project. The benefits of this project were a significant increase in the students' emotional quotient and in the professors' emotional skills.

Analysing the presented kinds of application of emotional education, it can be considered that there are different levels of strategies. At the teaching level, some professors try to promote a discussion of social-emotional skills in their classes. When emotional education becomes a program policy, a greater number of students have the opportunity to get involved in extended programs with different learning experiences. But, when emotional education is an institutional guideline, not only students but also professors could have the opportunity to be emotionally educated. Evidently, the results of an institutional initiative are broader when professors become multiplier agents of the process.

3 Workshop "Emotional Intelligence: tips and practices towards balance"

3.1 Context - Trails of Learnings Project

This paper presents the results of a case study, through an experience report of an 8-hour workshop offered to the community of the Federal University of Itajubá - Itabira campus, Brazil. The title of the workshop was "Emotional Intelligence: tips and practices towards balance", as shown in Figure 2.

Figure 2: Divulgation folder of "Emotional Intelligence: tips and practices towards balance" workshop

The workshop was promoted by the university's Pedagogical Center in a larger project called Trails of Learning. In this project, teachers were invited to offer learning experiences on various topics, including soft skills.

With a purpose to understand the experiences of university students, the Trails of Learnings Project was based on the theory of integration, formulated by Tinto (2012), and on the theory of institutional affiliation, by Coulon (2008). For Tinto (2012), the chances of success in higher education (completion of the course) are directly related to the academic and social integration of the student, in the university environment, both in formal and informal aspects, and the parameters for this integration, in the academic and social aspect, are: good academic performance, more fluid and relaxed relationship with professors and staff, participation in extracurricular activities, in study groups and social relationships with different institutional subjects. According to Tinto (2012), the students integrated in both fields will hardly drop out (Tinto, 2012).

Coulon (2008) states that entering higher education represents the arrival in a new world and the transition from the condition of student to student, affiliation, demands three times, namely: time of estrangement, time of learning and time of affiliation when the student becomes a member of that new community by appropriating the rules and meanings relevant to the academy, acquiring social and cognitive skills for university practice, being able to masterfully exercise the student's job. The passage through these times can be faster or longer, more fluid or more painful, depending on the previous trajectory of the subject and the institutional organisation (Coulon, 2008). Therefore, the proposition of activities related to different themes and beyond the classroom seeks to contribute to the improvement of the experience and relationships in the academic environment, thus enabling a reduction of stress and difficulties strictly related to academic learning.

Within the Trails of Learnings Project, activities were carried out aimed to improve reading and writing practices for engineering education, life and career planning, leadership, oratory, among other themes. It is noteworthy that the inaugural talk of the Project had as its theme "The academic routine – reflections on mental health". This talk also welcomed new students and the academic community at the opening of the academic semester of 2022, which also marked the face-to-face activities, after almost two years of remote activities due to the pandemic caused by the Coronavirus (COVID - 19).

Throughout 2022, the Trails of Learning Project held 12 workshops and reached more than 100 students. The activities were face-to-face, but some were recorded, and the videos are available on Unifei's Education Center (CEDUC) YouTube channel.

In order to offer an emotional education experience, a professor from the area of applied social sciences accepted the challenge and prepared the workshop with the aim of promoting an introduction to the topic for the participants. The workshop was promoted to students, university workers and the external community. The content and dynamics of the workshop will be presented, which was offered in two meetings of 4 hours each. The workshop was organised into 8 steps, as follows.

3.2 Content - Day 1

1 - Evoking emotions: participants were shown several toys, each participant had to choose a toy and say what emotion that object evoked (Figure 3). This was an opportunity for participants to mention emotions, feelings and behaviours related to the mentioned emotions and collectively share how they deal with emotions. The instructor considered the participants' reports and led the discussion using the concept of Caruso & Salovey (2004) that emotion is not just important, but absolutely necessary to make good decisions, take action to solve problems, cope with change, and succeed.

Figure 3: Material used in the Dynamic Evoking Emotions

2- Emotions concepts: Some concepts of emotions were shown to participants, such as Ekman (2011) which consider basic emotions such as joy, sadness, fear, surprise, disgust, contempt and anger. The Goleman (2011) definition of emotion was shared as "a feeling and its distinctive thoughts, psychological and biological states, and range of propensities to act" (Goleman, 2011). As it was a practical workshop, the theoretical explanation of the concept was not explored but there was a special care to cite reputable authors.

3 - Emotional difficulties of brazilian students: In order to hear participants, students in the majority, talk about their emotion difficulties related to academic routine, it was presented the National Forum of Provosts for Student Community Affairs report (FONAPRACE, 2019) about emotional difficulties of university students in Brazil. In a sample of 424,128 students from Brazilian Federal Educational Institutions Superior (IFES), 83.5% reported experiencing some type of emotional difficulty in the last 12 months. Anxiety was the most prevalent symptom (63.6%). Discouragement and lack of motivation were also symptoms frequently found in this study (45.6%). Before this data, the participants agreed that all emotional difficulties mentioned in the study are common among them.

3.3 Content - Day 2

4- Emotional mimicry: to experience the importance of recognizing one's own and others' emotions, a dynamic group was proposed, done in pairs, in which participants had to express an emotion and represent it to a colleague so that the emotion represented by mime was discovered by the other colleague. This was a funny dynamic that provided participants a moment of relaxation. At the time of debriefing this dynamic, it was possible to discuss skills related to empathy and the self-awareness of emotions.

5 - Self-awareness canvas: a self-awareness canvas was proposed to participants. According to Eurich (2017), one must follow seven insights to grow the self-awareness, or the capacity of knowing oneself. As advocated by Eurich (2017), self-awareness is a meta-competency that must be acquired before developing the other soft skills. In this sense, Eurich (2017) defends that there are seven forms of insight, all of which must be developed to become wholly self-aware. Participants were invited to use an A3 canvas (Figure 3) with the 7 seven insights: values, passions, aspirations, fit, patterns, reaction and impact. After participants fill out their canvas, it was considered that emotional intelligence relies on self-awareness as someone can only reach their full potential when this person knows her/himself enough to make the best decisions in view of his/her personal goals.

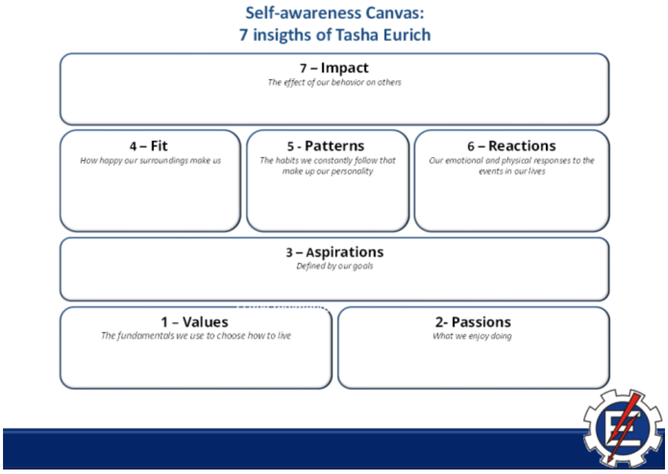

Figure 4: Self-awareness canvas - 7 insights of Tasha Eurich

6- **Emotional Intelligence concept:** the concept of emotional intelligence was presented to participants. According to Salovey and Mayers (1990) it is a type of social intelligence that involves the ability to monitor one's own emotions and both others, discriminate between them, and use information to guide one's thoughts and actions (Salovey & Mayer, 1990). A brief history of the popularisation of the term was presented mainly through the work of Goleman (2011) who says that emotional intelligence refers to being more intelligent in our emotional life: more self-awareness, more ability to deal with disturbing emotions, more sensitivity to deal with the emotions of two others – and place everything at the service of building effective and healthy relationships.

7- **Emotional Intelligence Techniques:** as practical exercises of emotional intelligence, two techniques were presented so that the participants could practise the awareness of their emotions and their reflexes in daily life. The first was the Emotional Diary, based on rational-emotive behavioural therapy by Ellis (1971), as placed in Figure 4. The Emotional Diary led the participant in a process of self-reflection and awareness of the effects of daily events, the emergence of emotions, thoughts and behaviours. In this diary, the participant is invited to reflect on how to re-signify events and choose more productive decisions in future situations.

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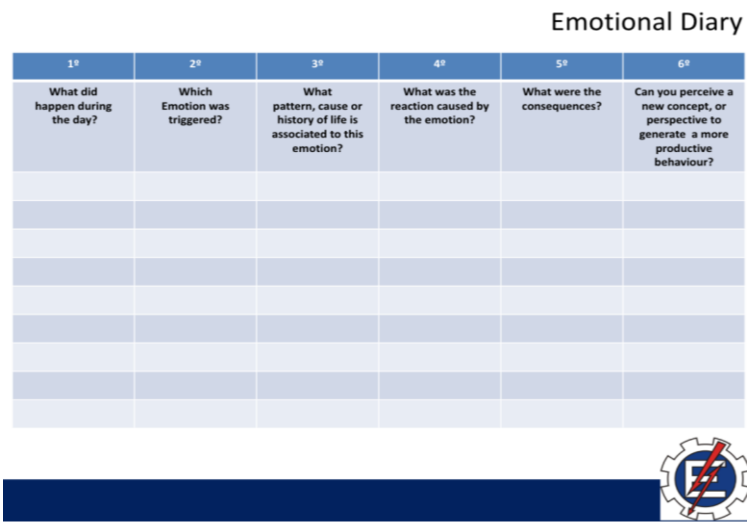
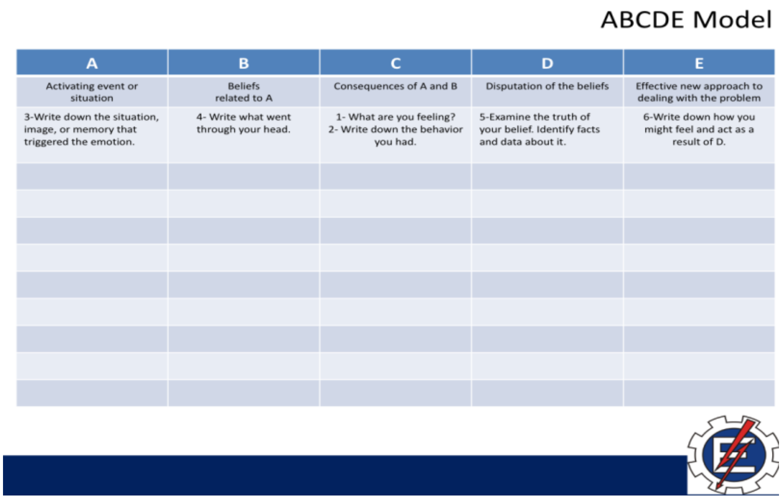

Emotional Diary

1º	2º	3º	4º	5º	6º
What did happen during the day?	Which Emotion was triggered?	What pattern, cause or history of life is associated to this emotion?	What was the reaction caused by the emotion?	What were the consequences?	Can you perceive a new concept, or perspective to generate a more productive behaviour?

Figure 5: Emotional Diary

The second technique that was presented to participants was the ABCDE model (Figure 6). It is a behavioural therapy model that guides the participant through five stages: 1) Activating event or situation, 2) Beliefs, 3) Consequences, 4) Disputation of the beliefs and 5) Effective new approach to dealing with the problem. The purpose of this model is to challenge an individual's negative or unhelpful beliefs and replace them with new, helpful ways of thinking. In addition to this model, the concept of cognitive distortion (Beck, 2022) was presented in order to help students to deal with unfounded thoughts that disturb productive behaviour.


ABCDE Model

A	B	C	D	E
Activating event or situation	Beliefs related to A	Consequences of A and B	Disputation of the beliefs	Effective new approach to dealing with the problem
3-Write down the situation, image, or memory that triggered the emotion.	4- Write what went through your head.	1- What are you feeling? 2- Write down the behavior you had.	5-Examine the truth of your belief. Identify facts and data about it.	6-Write down how you might feel and act as a result of D.

Figure 6: ABCDE Model

8- Emotional Intelligence Questionnaire: a self-assessment questionnaire was proposed to participants as a tool of self-reflection about their emotional intelligence skills. It was designed according to Goleman (2011) that considers the following emotional intelligence skills: self-awareness; managing emotional behaviours; self-motivation; empathy and social skill. This questionnaire was created and disseminated by NHS England in the Program Leading Across London (2014). Answering this questionnaire, the participants were invited to assess and score 50 statements related to emotional intelligence skills. After that, they could interpret the totals for each area of emotional intelligence, analysing their weakness and their strengths. At the end, they were asked to Consider the results and identify one or two actions that could be taken immediately to strengthen their emotional intelligence.

4 Conclusion

This paper aims to show an initiative that was held at Federal University of Itajubá – Itabira campus, Brazil. It was a possible strategy to include emotional education in this institution. Therefore, by discussing soft skills, and specifically Emotional Intelligence, it sought to provide tools to facilitate the academic integration and affiliation process, as formulated by Tinto (2012) and Coulon (2008), thus contributing to the successful permanence in the chosen undergraduate program.

The participation in the activity, by different students, also indicates the need to rethink the formal engineering curriculum. In doing so, actions like this can be present throughout the five years of graduation. It also seems to be important to involve other agents in the academic community, including professors and institutional managers, once emotional education is necessary not only to students but also to university staff.

Finally, in order to better understand the effects of these activities on directly improving learning, in addition to reducing dropout rates, more systematic research is still needed. It is important to monitor undergraduate students in the short, medium and long term. It is known that dropping out of the undergraduate program is a problematic situation for higher education and engineering education. It is a phenomenon that involves multiple factors such as conditions for entering higher education, institutional profile and economic context. Thus, emotional education and its support for efficient academic integration and affiliation is just one of the keys to understanding this complex situation.

For this context, it is important to improve the workshop reported here by inviting other members of the university such as the psychological service and the social assistance service in order to offer a more robust learning experience. Yet, there is the intent to offer this content as a permanent initiative.

Moreover, it is important to say that emotional education has its boundaries. It is suitable for participants that are able to manage their emotional difficulties in a healthy way and to learn and apply some concepts and techniques offered in the emotional educational context. It must be emphasised that participants must seek professional help in case of mental health problems that meet the formal criteria for diagnosis.

5 References

Arroyo-Herrera, M., Mata-Salas, A., Coto-Sarmiento, L., Vega-Agüero, J., Brenes-Cerdas, M., & Hernández-Jiménez, M. T.
(2019, September). Development of Emotional Intelligence in Computing Students: The "Experiencia 360" Project. In 2019 XLV Latin American Computing Conference (CLEI) (pp. 1-9). IEEE.

Beck, J. S. (2022) Terapia cognitivo-comportamental: teoria e prática. 3 ed. Porto Alegre: Artmed.

Caruso, D. R., & Salovey, P. (2004). *The emotionally intelligent manager: How to develop and use the four key emotional skills of leadership.* John Wiley & Sons.

Casado, M. L., López, D., & Lapuerta, V. (2016). Socio-emotional competencies in Engineering Education. *International Journal of Engineering Education*, 32(4), 1660-1678.

Chisholm, C. The formation of engineers through the development of Emotional Intelligence and Emotional Competence for global practice, *Global Journal of Engineering Education, GJEE*, 12(1), 2010, pp.6–11.

Coulon, A. (2008). *A condição de estudante: a entrada na vida universitária*. Salvador: Edufba.

Ekman, P. (2011). A linguagem das emoções. São Paulo: Lua de Papel, 77-108.

Ellis, A. (1974). Rational-emotive theory: Albert Ellis.

Eurich, T. (2017). Insight: The power of self-awareness in a self-deluded world. Macmillan.

Fórum Nacional de Pró-Reitores de Assuntos Comunitários e Estudantis - FONAPRACE (2019). *V Pesquisa Nacional de Perfil Socioeconômico e Cultural dos(as) Graduandos(as) das Instituições Federais de Ensino Superior.* http://www.andifes.org.br/wp-content/uploads/2019/05/V-PesquisaNacional-de-Perfil-Socioeconômico-e-Cultural-dos-as-Graduandos-as-das-IFES-2018.pdf

Goleman, D. (2011). Emotional intelligence. Objetiva.

Leading Across London. (2014) Emotional intelligence questionnaire. Outcomes measurement tool: attitudes & feelings – emotional intelligence. London: NHS England. https://www.drugsandalcohol.ie/26776/1/Emotional_intelligence_questionnaire-LAL1.pdf

Lopes, F. M., Lessa, R. T., Carvalho, R. A., Reichert, R. A., Andrade, A. L. M., & De Micheli, D. (2022). Transtornos mentais
comuns em estudantes universitários: uma revisão sistemática da literatura. *Revista Psicologia em Pesquisa*, 16(1), 1-23.

Riemer, M. J. (2001). IQ versus EQ: Emotional intelligence and the graduate engineer. In Proc. *5th Baltic Region Seminar on Engng. Educ* (pp. 79-82).

Salovey, P., & Mayer, J.D. (1990). Emotional intelligence. *Imagination, Cognition, and Personality*, 9, 185-211.

Tinto, V. (2012). A theory of individual departure from institutions of higher education. In: TINTO, V. *Leaving College:*
rethinking the causes and cures of student attrition. Chicago: The University of Chicago Press. pp.84-137

Vipin, B., Panicker, V. V., & Sridharan, R. (2012, July). Transformation process in engineering education: A holistic approach.
In 2012 *IEEE International Conference on Engineering Education: Innovative Practices and Future Trends (AICERA)* (pp. 1-4). IEEE.

Zysberg, L., & Le, H. X. (2018). Emotional Education: A Selective Literature Review and an Emerging Model. *Educational Research and Theory*, 1, 37-50.

Biomechanical Project Design: Development of a Pump for Mechanical Circulatory Assistance

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Abstract

Future engineers must be prepared to work in a reality where the industrial and service sectors are changing rapidly. In addition to the necessary technical training, students must develop skills such as complex problem solving and the ability to learn and work in teams. A project-based course is a very effective way to prepare students to face real problems and develop these skills. This work describes a project-based course that is grounded on a case study of a patient with a severe heart failure refractory to pharmacological treatment. It is the typical case when there is nothing else to do with this patient from a purely medical point of view. It is a patient who has a major impairment of his quality of life and is on the waiting list for a heart transplantation. So, the challenge is an engineering solution to improve the patient's quality of life. Although the course has a strong focus on technical content (i.e., fluid mechanics, biocompatibility, electro-medical devices, Computer Aided Design and Simulation) it also addresses several complimentary educational objectives, since the project is developed in teams, involves ethics and professional responsibilities in engineering activities, demands knowledge about regulatory requirements and management of resources and deliverables. Assessing all these topics is a very difficult task, but several assessments are made during the course through progressive stages of student deliverables. The course is taught by two professors with the help of four technicians of two different laboratories and usually has about twenty-five students. It is interesting to compare the autonomy and skills developed by the students during the first and last stages of the project. Course assessments are used throughout the engineering program to enhance the student development cycle.

Keywords: Active Learning; Engineering Education; Project Approaches.

1 Introduction

Engineers must be prepared to work in a challenging professional environment where industrial and service sectors are constantly and rapidly changing and much has been said about the need of developing the profile of professionals who will be at the forefront of this scenario (Dym et al, 2005).

In the current engineering work environment, industrial and services sectors are constantly and rapidly changing, and the modernization leads to the use of increasingly autonomous machines, capable of making complex decisions, based on a large amount of information. This scenario requires technically skilled engineers, also able to focus on the control and strategic planning of the projects. In addition to multidisciplinary technical knowledge on several correlated areas, it is necessary to develop important skills such as collaborative work, analysis, and adaptation skills (Lopes et al, 2021). The engineer must see the world from multiple perspectives: technical, sociocultural, political-legal, ethical, environmental, economic, etc. Since this professional will be dealing with several areas and diversity, it is essential to learn to work as a team and to communicate effectively, giving and receiving feedback. In many companies, the engineer plays a leading role and therefore must develop the potential to coordinate activities while monitoring the progress of other team members. If the market is increasingly requiring this type of professional, it is extremely important that educational institutions provide this qualification.

Among possible approaches to prepare the students to face real problems, project-based learning (PBL) courses are very effective options. Students begin to explore aspects of design, entrepreneurship, and teamwork, in addition to understanding the engineering context from the first steps. In this way, students' autonomy (their feeling of being able to carry out and build projects) also grows and, by understanding their learning needs, they become protagonists in their own development (Dym et al, 2005). Additionally, PBL promotes students' motivation and improves their outcomes. They not only acquire better technical training, but also improve their transversal skills (Rodríguez et al, 2015).

This paper will present a project-oriented course whose theme is the use of mechanical engineering concepts in the solving of problems of medical interest. Technical aspects of the course will be presented and confronted with the expected learning objectives in the institution's mechanical engineering program. In topic 2, an introduction to the theme of Project Based Learning and Student Motivation will be made, in topic 3, a description of the theme proposed for the case study will be presented and in topic 4, the learning objectives of the mechanical engineering program at INSPER will be emphasized. Next, in the item methodology, the sequence of activities that are developed by the students during the course is described. Finally, the conclusion item presents an analysis of the observed results.

2 Project Based Learning and Student Motivation

According to Graaff & Kolmos (2003) Problem-based learning (PBL) is an educational approach whereby the problem is the starting point of the learning process. Usually, the problems are real-life problems which have been selected and edited to meet educational objectives and criteria. It is crucial that the problem serves as the basis for the learning process because this determines the direction to be followed during the learning process. This also allows the learning content to be related to a specific context, giving meaning to the course contents in a way that the student understands why he/she is studying those courses contents at that time increasing student motivation and comprehension (Green 1998, Thomas 2000 and Frank et al 2003). Additionally, in PBL, students develop skills that are increasingly in demand in the real world, that the classical methods are less efficient to accomplish (Saunders-Smits & de Graaff, 2003).

Students' motivation is dependent on the degree of participation—the more decisions the students are able to make, the greater their motivation. Even though there are specific learning objectives, the student must have enough freedom to get the maximum enjoyment from the work. Three fundamental types of project work can be distinguished: the task project, the discipline project, and the problem project (Kolmos, 1996). The task project is characterized by some degree of planning and direction on the part of the teacher (teaching objectives) involving a large task that must be solved. The discipline project is usually, though not necessarily, characterised by a fairly high degree of direction from the teacher (study programme requirements), in that the disciplines and the methods are chosen in advance. The problem project is a full-scale project in which the course of action is not planned in detail by the teachers. The problem formulation directs the choice of disciplines and methods and the problem itself arises from the problem-oriented theme.

In our case, the problem and the subject-oriented methods are chosen in advance, so that, for the student, the primary concern is to complete the project according to the guidelines provided. Therefore, we could consider that the PBL case that best suits our case is the discipline project, as the project theme is chosen in order to develop technical skills on a specific group of disciplines that comprises fluid mechanics, biocompatibility, sealing machine elements, prototyping and project development methodology. To assure student motivation in that they should feel that the project belongs to them (and not the teacher) some important decisions are left to them in the project development process. In this way, students' autonomy (their feeling of being able to carry out and build projects) also grows and, by understanding their learning needs, they become protagonists in their own development.

3 Thematical problem of the Case Study

The case of the discipline is a patient who has a major impairment of his quality of life and is basically on the waiting list for a heart transplantation. This patient is already fully medicated, but the pharmacological therapy is not capable to retrieve the patient´s normal quality of life. The unique possible solution to improve the patient's quality of life is a heart transplantation. Some statistical data suggests that every year 40000 patients are candidates for a heart transplantation but only 2500 heart transplants are made per year in the USA. In our country, Brasil, something around 400 transplants is done every year. So, there is a shortage of natural hearts to solve the problem which creates an opportunity for an engineering solution. The proposal challenge to the students is an engineering solution to improve the patient's quality of life. The solution is a pump to overtake partially or fully the heart function of pumping blood. The students will have to specify, define, and implement a prototype that will be validated in a bench at the end of the semester.

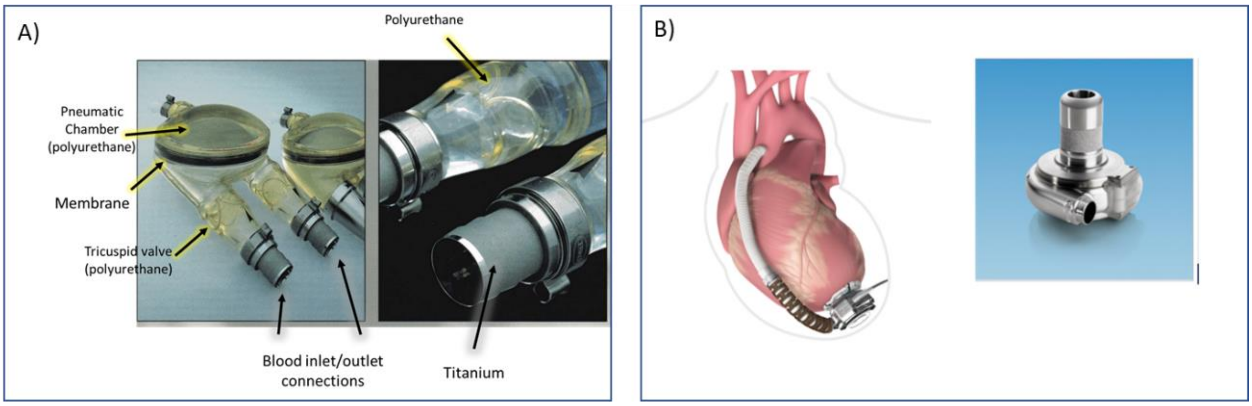

Figure 1. Two main types of commercial cardiac pumps . (A) The Berlin Heart pulsatile type pump. (B) The Medtronics Heart Ware rotary type pump.

4 Learning Objectives

The Mechanical Engineering Program at Insper expects the graduates within a few years of graduation to attain the following:

1. use analytical skills and technical knowledge to design effective solutions to complex engineering problems.
2. be agents of innovation, guided by the needs of the user and society in a constantly changing market.
3. lead teams and mobilize resources to implement sustainable, economically, and ethically viable ventures.
4. use effective communication to develop and work in multidisciplinary and diverse teams.
5. be constantly oriented to expand learning skills at different competence levels, seeking continuous improvement.

Although the Biomechanical Project Design course has a strong focus on technical content (i.e., fluid mechanics, biocompatibility, electro-medical devices), observing the list above, the course can be considered a valuable contribution to address several of the educational objectives, since the project is developed in teams, involves ethics and professional responsibilities in engineering activities, requires technical knowledge and experimentation to design, simulate, manufacture and assemble a medical device and also base the research of user demands and regulatory requirements, also complemented by the management of resources and deliverables. More details about the course activities are described in the next sections.

5 Methodology

The students are divided in groups of 3 to 5 students according to the size of the class. In general, classes are formed by 20 to 30 students.

The project follows the Insper framework for project development, where the accomplishment of each step is evidenced by the production of a deliverable. (Table 1)

Table 1. Project Development Framework for the case of a pulsatile artificial heart. FMEA: Failure Modes and Effects Analysis. CFD: Computational Fluid Dynamics. CAE: Computed Aid Engineering.

Technical Proposal				Technical detailing				CAE simulation	Validation
Delivery 1: Proposal for the developme nt of a new project	Delivery 2: Research Analysis: Benchmark ing + Technical specificatio n	Delivery 3: FMEA	Gate 1: Approval of the Technical Proposal	Delivery 4: 3D Model of the Valve + Detailing	Delivery 5: 3D Model Pump + Detailing	Delivery 6: Membrane mold and valve	Gate 2: Release to manufac-turing	Delivery 7: CFD	Delivery 8: Final Report (validation tests + biocompati bility discussion)

The first stage involves the development of the technical proposal characterized by three deliverables. The first delivery is the proposal for the development of a new project. This delivery corresponds to the proposal of a new project that is made to be delivered to the top management of the company, in a real case of a project developed in the industry or in an engineering corporation. In this delivery, students need to explain the characteristics of the project that can meet the solution of the proposed problem.

At the second step of development of the technical proposal a research analysis is done that, due to the fact that a solution to the presented problem already exists, where many of the possibilities can be seen in Mascio (2015), the best approach is the development of a benchmarking analysis. Through benchmarking, students acquire a state-of-the-art vision for this technology. In figure 1 is shown the two types of solution that can be chosen for, as the mechanical assist circulatory pumps are divided in two groups: The pulsatile and rotary type ones. A lottery is made among the students of the cardiac pumps models that exists in the market. A seminar is done where each group presents an overview of the pump they were sorted in order to give awareness of the subject between them. At this point, the students are already capable of defining the technical requirements for a cardiac pump, and each group creates a document with the technical specifications of the equipment to be developed. Here the students need to specify the requirements of the pump to attend the body constrains that consider not only requisites of the cardiovascular physiology of the human body, but also the requisites of biocompatibility and hemocompatibilty that the pump needs to fulfil. To prepare the students to this task, the course gives three introductory lectures where a revision of topics of cardiovascular physiology, blood pumps for mechanical cardiovascular assistance, biocompatibility and hemocompatibility is done by the professor.

At this point, arises an important motivational opportunity for students, as they must choose the most appropriate solution for the pump through a decision matrix. An example of parameters used in the decision matrix is shown in figure 2.

	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Decision
Option1	+	+	?	+	-	+2
Option2	+	-	+	+	+	+3
Option3	+	-	+	?	-	0
Option4	-	-	-	?	?	-3

Figure 2: Decision matrix for the pump type selection.

In the case of the option for the pulsatile pump, for example, a second opportunity to choose a solution is made in choosing the valve model that will be implemented for the artificial heart.

The third delivery is a Failure Mode and Effect Analysis (FMEA) report, where the students must provide risk analysis and possible solutions for several aspects of the chosen solution. This stage requires acknowledge of normative documents.

It is possible to observe that the students have difficulties with these three first steps, being a very good challenge, since they are not used to prepare this kind of documentation and they must develop the ability to predict failures and mitigate risks, especially in the health area, where there are very restricted standards.

Once the technical proposal stage is completed, an Approval Gate (Gate 1) takes place through a discussion round table in which the technical specification is approved or goes through a review process.

In the next stage of the project, the Technical Detailing phase begins.

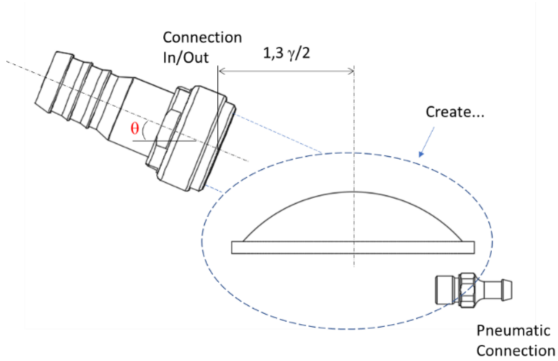

Figure 3: Some parameters are specified to orient the project development (θ, γ).

Some geometric parameters are specified in advance to avoid too many dimensional reviews of the project (Figure 3). If the students chose for the Pulsatile pump project, for example, 3 deliverables are defined: A) 3D modelling of the valve B) 3D modelling of the cardiac prosthesis and C) 3D modelling of the membrane mould (figure 4) and the valve mould, in the case the students have chosen a valve with a polyurethane leaflet (figure 5).

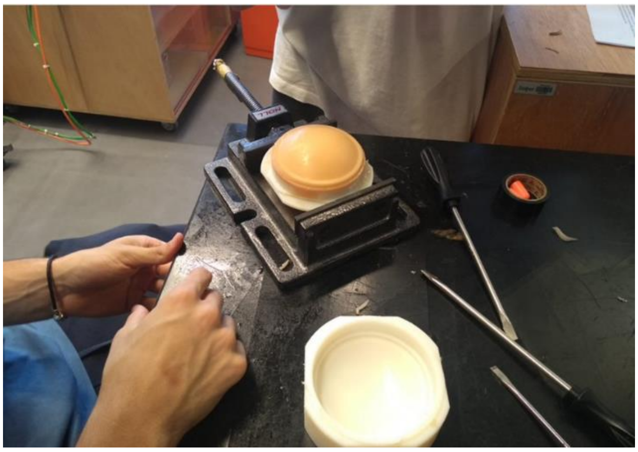

Figure 4: production of the membrane for the pulsatile pump through a membrane 3D printed mould.

Student deliveries are corrected by the professor. If there is a need for revision, students will be informed through feedback. Finally, once the technical details are approved, this is done through a release gate for manufacturing (Gate 2). The parts of the artificial heart are manufactured by 3D printing, although some metallic connections are manufactured by CNC machining.

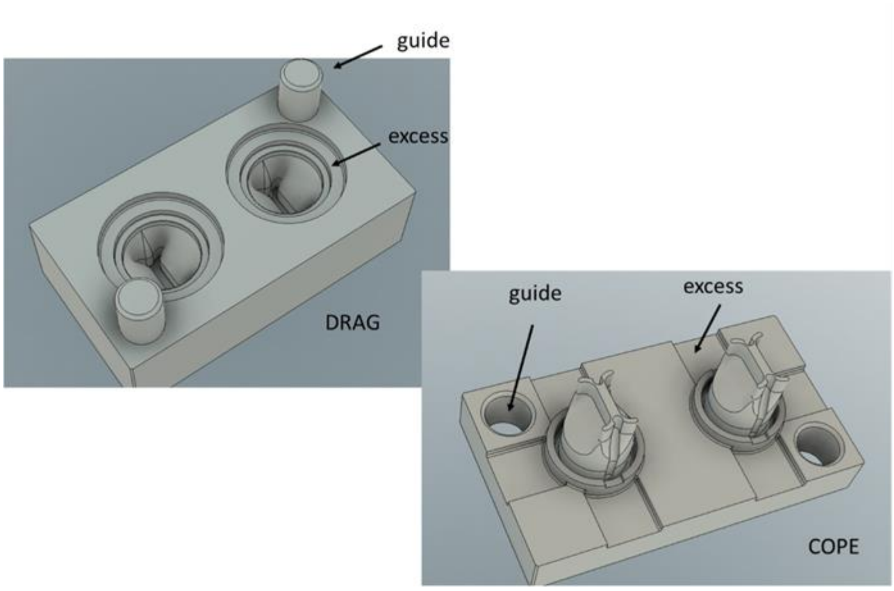

Figure 5: 3D model of the polyurethane (bicuspid) valve mould.

In parallel to the manufacturing stage, the students begin to develop a computational analysis of the blood flow in the artificial heart outlet valve (figure 6), which is the most critical point of the blood flow in the equipment. This analysis will be an important validation strategy for the equipment regarding its biocompatibility. The objective at this phase of the project is to calculate the pressure and velocity fields (figure 7) of the flow which can be used to predict the haemolyses index and thrombus formation applying experimental models (Giersiepen et al, 1990).

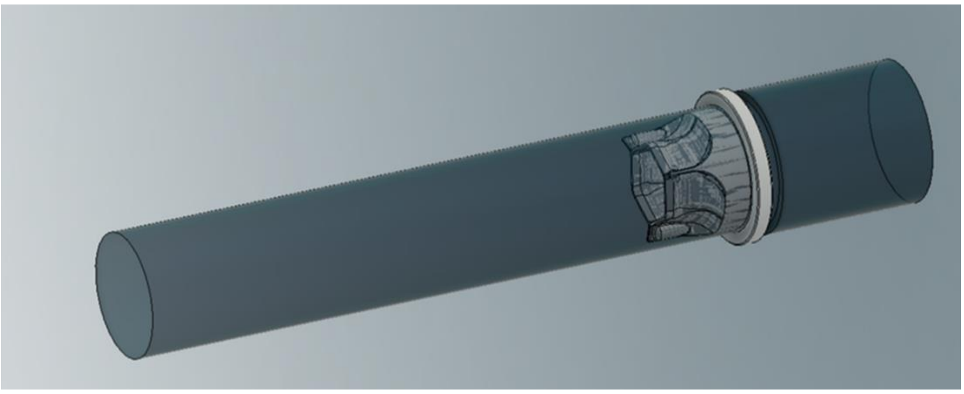

Figure 6: Fluid domain for the CFD simulation of the blood flow through the exit valve (tricuspid) of the artificial heart

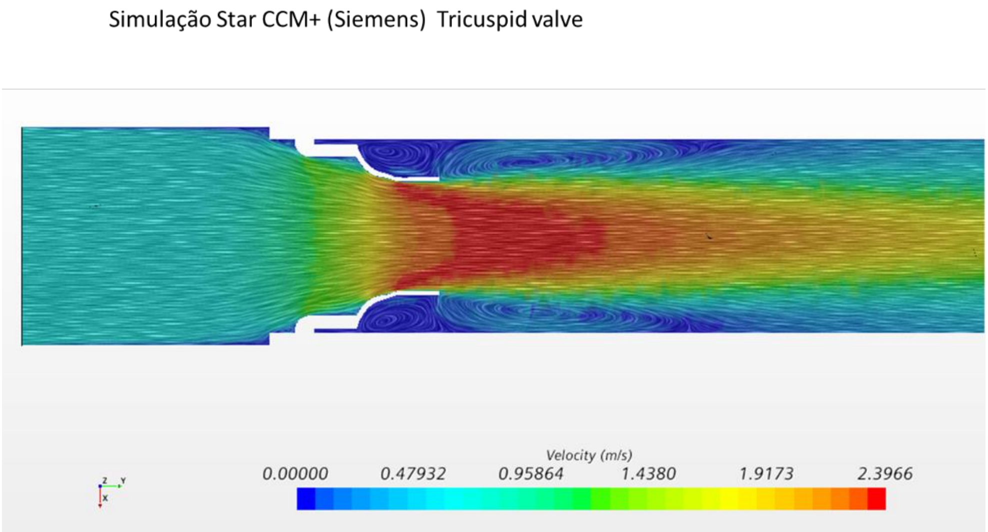

Figure 7: Velocity magnitude at the exit valve (tricuspid) of the artificial heart.

Once the manufacturing of the cardiac prosthesis parts is completed, the final assembly is carried out.

For the operation of the prosthesis, a pneumatic propeller developed at the institution will be used, for the case of the pulsatile pump, and an electric motor for the case of the rotary pump. In the case of the pulsatile pump, the prosthesis is connected to the propeller through a pneumatic line and the blood inlet and outlet connections are connected to the cardiovascular simulator in the laboratory. Here static and dynamic validation tests are developed. Static validation consists of testing the sealing of the pneumatic chamber to detect possible air leaks and also possible blood leaks in the prosthesis, which is done by filling it with water. Once the prosthesis has passed the sealing tests, the equipment is dynamically validated (figure 8). In this step, verification is carried out whether the pump's performance meets the previously specified performance regarding the physiological values of volume flow, that is, the patient's cardiac output and the mean arterial pressure.

Therefore, the developed project is validated for its biocompatibility in a virtual way and for its hydrodynamic performance on a physical bench.

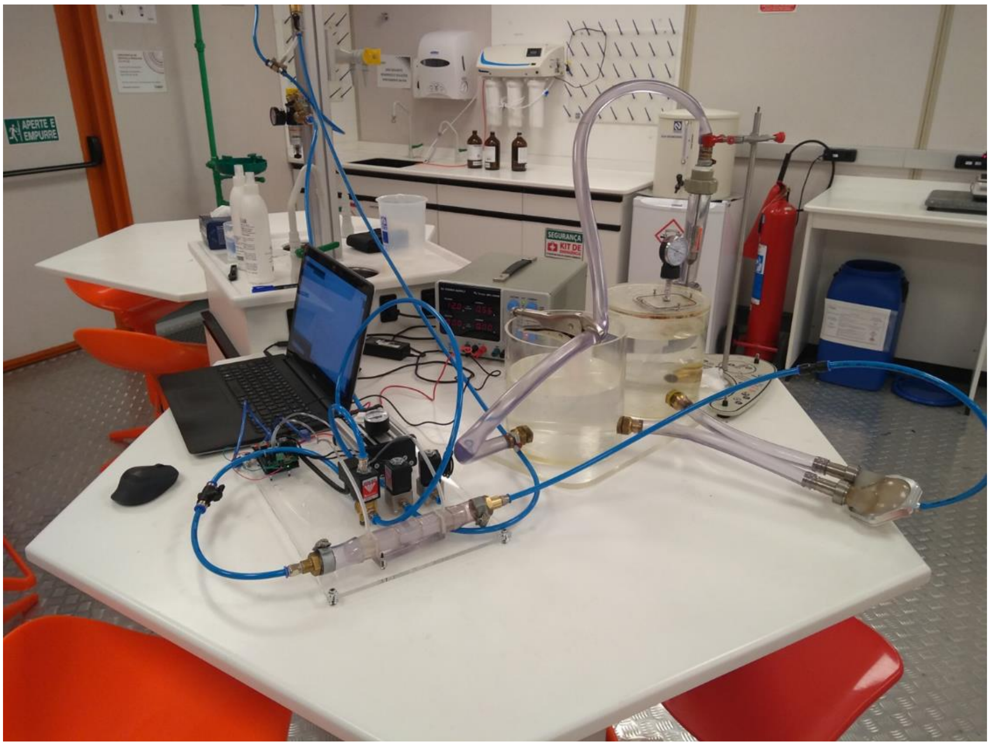

Figure 8: Dynamic bench testing of the artificial heart prototype.

6 Conclusion

This work presents the use of project-based learning methodologies, widely used over the institution's programs. It addresses the project developed in the sixth period of the Mechanical Engineering program, after the student has already developed a series of projects throughout the first periods and has been able to acquire some of the necessary skills to develop more complex projects, such as the one in the Biomechanical Project Design course.

As the degree of complexity of projects increases along the program, the density of technical knowledge addressed in the subjects increases, providing bases for the so-called 'project design courses'. In addition, the ability to manage resources and take care of the progress of the project ends up also having a greater focus. In this way, the search for the necessary knowledge to carry out the projects is encouraged, contributing to the increase of the student's autonomy (their feeling of being able to carry out and build projects). Through the understanding of their learning needs, they become protagonist in their own development.

The major difficulties observed in students refer precisely to the reflection of this autonomy. In this course, this is observed in particular during the first stages, which depend on the student's greater ability to seek technical knowledge and also knowledge belonging to the medical area, outside their usual area of knowledge, with specific restrictions and norms. This provide a broad development of awareness context and adaptability, reflecting the experiences that will be found in their work environment.

In addition, professor-student interaction increases considerably, as decisions and analyses in project management and related to technical issues become more complex and, for the faculty, this type of approach usually generates greater dedication, present from the prototyping stages of the project course, even before the course is offered.

However, the result obtained is largely satisfactory, from the point of view of student skills development. The project courses provide very consistent bases for students' intellectual autonomy, which will be more widely demanded in the Final Engineering Project (FEP), which is the Capstone Project of the program. FEP is carried out in partnership with companies to solve real problems. It is worth noting that student outcomes assessments on Design, Entrepreneurship, Organization, Teamwork, Technical Execution, Communication are evaluated in the Capstone Project and serve as feedback for eventual adaptations in the project courses, including Biomechanical Project Design.

In this way, there is always feedback and feedforward information throughout the program, in order to improve the student's development cycle, always seeking to provide a solid and broad education so that the future engineers are able to face the challenges of the increasingly demanding labour market.

7 References

Dym, C.L., Agogino, A.M., Eris, O., Frey, D.D. and Leifer, L.J. (2005), Engineering Design Thinking, Teaching, and Learning. *Journal of Engineering Education*, 94, 103-120. https://doi.org/10.1002/j.2168-9830.2005.tb00832.x

Frank M., Lavy I., Elata D. (2003), Implementing the project based learning approach in an academic engineering course. *International Journal of Technology and Design Education*, 13, 273–288.

Giersiepen M, Wurzinger LJ, Opitz R, Reul H. (1990) Estimation of shear stress-related blood damage in heart valve prostheses--in vitro comparison of 25 aortic valves. *International Journal of Artificial Organs*. May;13(5):300-6. PMID: 2365485

Graaff, E. d., & Kolmos, A. (2003). Characteristics of Problem–Based Learning. *International Journal of Engineering Education, 19*(5), 657-662.

Green, A.M., (1998). Project-based-learning; moving students toward meaningful learning. ERIC Database, ED422466

Kolmos A., (1996) Reflections on project work and problem-based learning, *European Journal of Engineering Education*, 21(2), 141-148.

Lopes, D. C., Gerolamo, M. C., Musettia, M. A., Amaral, D. C., (2021) Social skills in higher education: how to combine active learning and social skills training program. *Production*, 31, e20200103.

Mascio C. E. (2015). The Use of Ventricular Assist Device Support in Children: The State of the Art. *Artificial Organs*, 39(1):14–20

Rodríguez, J., Laverón-Simavilla, A., del Cura, J. M., Ezquerro, J. M., Lapuerta, V., & Cordero-Gracia, M. (2015). Project Based Learning experiences in the space engineering education at Technical University of Madrid. *Advances in Space Research*, *56*(7), 1319-1330. http://dx.doi.org/10.1016/j.asr.2015.07.003

Saunders-Smits, G.N., de Graaff, E., 2003. The development of integrated professional skills in AE through problem-based learning in design projects. In: *Proceedings of the 2003 American Society for Engineering Education Annual Conference & Exposition*.

Thomas, J.W., 2000. A review of research on project based learning. Report prepared for The Autodesk Foundation. http://www.autodesk.com/foundation/pbl/research

Developing Teamwork with the aid of Reflection

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Abstract

The development of students' teamwork skills goes beyond simply grouping them to work on projects together. The act of becoming a team depends on a process; in addition to their team tasks, students enhance teamwork learning when they receive external support and guidance. Based on active learning principles, the experience of working in teams is complete when it includes observation and reflection as components of learning.

A solution is to provide structured peer evaluation resources (CATME®) associated with team coaching sessions after team task experiences. This structure helps students to reflect on knowledge about their colleagues, while improving their empathy and communication skills. There is a need for some prework to prepare students in interpersonal communication before the coaching sessions.

We aim to report the results of using a similar framework during the second semester of a computer science course. In this class, students were encouraged to participate in meetings with a coach, and at the same time, they worked in teams to develop a project focused on solving real problems. In parallel, we collected two sets of data: the progress of quality indicators of peer evaluations exhibited a positive trend, but not significant, requiring additional research, while the students reported in the questionnaire that the coaches' support was of significant value for the proper functioning of the team, especially in situations such as defining the best way to give negative feedback. Together, the results endorse the continuation of the research to improve sample size and confirm the positive effects of coaching in teamwork development.

Keywords: Active Learning; Engineering Education; Inclusion of emotions in engineering education; Collaborative Learning; Soft skills.

1 Introduction

Companies increasingly need teams for their results (Kozlowski & Ilgen, 2006). Teams can overcome the complex challenges that arise (Mathieu, Heffner, Goodwin, Cannon-Bowers, & Salas, 2005) and develop innovative solutions (Sundstrom, De Meuse& Frutell, 1990). Organizations require many skills to achieve such results, and teams bring them together (Kozlowski & Ilgen, 2006). However, a team is not the sum of individual competencies (Kozlowski & Klein, 2000). Specialization generates results only through interactions between team members collaborating to build team deliverables (Rouse, Cannon-Bowers & Salas, 1992). Another way to think about this view is that solving organizational problems requires the involvement of multidisciplinary and distributed knowledge (Sloman, Fernbach, 2017).

Business schools prepare students by developing their skills to work in organizations. Due to the relevance of teamwork competence has for organizations, business schools are increasingly adopting teamwork as part of student activities. However, organizations recurrently express dissatisfaction with the student's preparation when they start their careers; the way schools introduce teamwork is not producing results. Prichard, Stratford, and Hardy (2004) explain that schools try a simplistic approach to develop teamwork, just adding team projects to courses with the premise that the opportunity of team experience would be enough for learning (Porter, 1993).

One solution for this deficiency is adopting of a feedback process executed through a peer evaluation tool (Rosenstein, 1994; Harris & Barnes-Farrell, 1997; McGourty & De Meuse, 2001; Ohland et al., 2012). This resource collects information from team members about their contributions and their team's experiences, including self and peer assessments of their team members' teamwork competency. The tool may share peer evaluations with students, helping them to know their performance during teamwork projects, while allowing the identification of their development gaps.

Meanwhile, the addition of peer evaluations may not be enough to stimulate learning. We explore this question analysing the whole teamwork development process when including the peer evaluation tool in team projects. Based on the fundamentals of experiential learning (Kolb, 2014), the resulting learning process could be improved. According to a proposition from Hackman & Wageman (2005), we implemented a team coaching activity to enrich the learning capacity of the development process, completing the experiential cycle with a reflective activity.

While team coaching continues to grow as a method to develop team performance (Widdowson, L., Rochester, L., Barbour, P. J., & Hullinger, A. M., 2020) and organizations expect to improve its utilization over next years (Mann, 2015), this type of coaching represented only 9% of total coaching in 2015 (Mann, 2015). Besides the small representation that team coaching represents as a technique to improve team effectiveness in organizations, this limitation also occurs in the research field, in which the subject is sparse (Hastings, R., & Pennington, W., 2019), and the scarcity of research and use of team coaching in education is consequential.

This study intends to explore the effects of team coaching in educational settings as a tool for developing students' competency in teamwork, preparing them to face the difficulties brought by organizations when integrating young graduates into teams because of the effects predicted and the scarcity of research data in this field.

2 Literature Review

Supporting organizational needs, this work focuses on teams according to the definition: (Cohen & Bailey, 1997, p. 241): "A team is a collection of individuals who are interdependent in their tasks, who share responsibility for outcomes, who see themselves and who are perceived by others as an intact social entity embedded in one or more larger social systems (for example, a business unit or the corporation), and who manage their relationships across organizational boundaries".

Teams bring organizations performance benefits in tasks that are inadequate for individuals, such as tasks that are complex or require speed, or involve improvement on a product or service, and when involving customers (Levi, 2020). Organizations have expectations about gains in performance that teams might bring. Consequently, universities are pressured to develop students in teamwork competencies (Dunne & Prince, 1997).

Meanwhile, universities do not appear to be prepared for the mission: a frequent solution was only to require the implementation of team projects into disciplines syllabus. The premise behind this idea is that the experience in teams accumulated by students along the courses would be adequate to promote teamwork development (Porter, 1993). Unfortunately, authors like Bowen (1998), Hertz-Lazarowitz (1989) or Porter (1993), inform that this idea fails to achieve its goal. The accumulation of experience given by means of repeated team projects might develop teamwork competencies if students have the essential skills naturally. Then, each new experience would improve their skills through training. However, if students do not have the skills required by teamwork, projects cannot aid any development without the help of a facilitator (Michaelsen & Black, 1994).

Teamwork is a competency, comprised of a set of interrelated knowledge, skills, and attitudes. Students need more than repeating team projects to train their existing competencies; they need to incorporate new skills and attitudes to close their gaps. An alternate approach to this development is experiential learning (Kolb, 2014), a learning frame that promotes the acquisition of skills thanks to a conscious process surrounded by resources that bring required knowledge from outside.

2.1 Experiential learning

The experiential learning frame may be supported by the team experiences that universities usually implement through projects. Meanwhile, it requires additional cognitive processes, necessary to generate conscious learning based on a purposeful reflection about the experience. The learning process should also be improved, bringing external knowledge related to the experience. In a complete experiential learning frame, development is enhanced by concrete experiences, complemented through reflective observation, and helped by related abstract conceptualization. The learning process may be reinforced by successive experiences when students progressively incorporate the knowledge (Kolb, 2014).

An individual case would illustrate how experiential learning can be applied to teamwork development. Suppose that Paula just finished a project in which her teammates claimed that she speaks too much. In a traditional learning approach, Paula will simply move to another project in the following academic period. Maybe she will learn something from the claims of their colleagues, but Paula will not have any help to reflect on her communication gap, and this learning probably will not happen.

With experiential learning, Paula could reflect on her communication performance. For instance, Paula would evaluate her speeches with teammates through an essay or hearing comments directly from them. Continuing the experiential learning cycle, Paula would think about how she could improve her communication skills in the next project based on reading an article about the subject. Paula would decide to train in active listening before the next move or simply to pay more attention to their teammates' speeches. Then, Paula would consciously try the new skill in the next project. The idea behind experiential learning is that cycles like the one simulated are continually repeated, creating continuous opportunities for learning.

2.2 Peer evaluation

Observation is part of experiential learning. A greater challenge is that such observation is not restricted to the classroom environment; it should include all moments in which the team operates (Loughry, Ohland, & Woer, 2014). Therefore, a teacher cannot perform the observation task, augmented by multiple teams with multiple members acting simultaneously. Auto and peer assessments are required as resources for observation.

Engineering schools have been focused on the development of peer evaluation systems to attend for the teamwork assessment need (Ohland, Layton, Loughry, & Yuhasz, 2005). One resource developed to support peer evaluation in teamwork was behaviourally anchored scales, which has been showing better reliability than other scales (Ohland, Layton, Loughry, & Yuhasz, 2005). Peer evaluations might be used to generate students' grades as part of the evaluation of teamwork development, a summative assessment. Meanwhile, Moran, Musselwhite, & Zenger, (1996) recommend summative instead of formative assessments to assure that students' evaluation is more precise, avoiding inflation due to bias generated by grade expectations.

2.3 Team coaching

A frame of experiential learning applied to teamwork should include reflective observation, meaning that the observation made by students (auto and peer) should be appreciated by them through reflection to provoke learning (Kolb, 2014). One way to obtain this reflection is to apply team coaching interventions (Hackman, & Wageman, 2005; Jones, Napiersky, & Lyubovnikova, 2019).

The effective contribution of team coaching to teamwork development under the frame of experiential learning depends on how it is applied, implying precision about what it is and how it acts. The recent work of Jones, Napiersky, & Lyubovnikova (2019) brought the following definition of what team coaching means:

> *"a team-based learning and development intervention that considers the team to be a system and is applied collectively to the team as a whole. The focus of team coaching is on the team performance and the achievement of a common or shared team goal. Team learning is empowered via specific team coaching activities for self and team reflection, which is facilitated by the team coach(es) through the application of coaching techniques such as impactful, reflective questioning which raises awareness, builds trusting relationships and improves communication. A team coach does not provide advice or solutions to the team. (p. 73)".*

This definition supports the reflective observation process required by experiential learning, demanding skilled coaches, capable of reflective questioning and that do not act as an advisor.

Jones, Napiersky, & Lyubovnikova (2019) distinguished between team coaching (realized in person with the entire team and coach facilitation) from individual coaching (one-to-one) and differentiating team coaching from other team interventions. Team training (focused on taskwork and development of competence required), team development (a short-term approach usually realized out of team context to develop teamwork, without the need to deepen problems), and team building (another kind of single event out of context that is focused on establish initial relationships) do not generate the reflective approach required by experiential learning. On the other hand, team coaching is a long-term approach consisting of repeated interventions, with the aim to explore barriers and impediments in teamwork that influences team performance, in which the team coach uses advanced reflective techniques to induce team members to enter difficult relationship matters.

In general terms, there are three opportune moments during a team's mission (Hackman, & Wageman, 2005) to apply team coaching: starting a team mission (team members alignment and commitment with objectives), mission midpoint (support for the problems that team is facing to achieve results), and at the end of a mission (learning through lessons learned).

2.4 Measuring outputs

Peer evaluations are inflated by students if they are not properly trained; teamwork measurements are valid only if validated by measuring the respective quality of observations. Indicators for observation quality were added to teamwork measurements. Both quality of teamwork observations and teamwork itself should be followed along team performances. Quality of observations validates teamwork performance because low levels of consistency on observations nullify their meaning.

2.4.1 Teamwork

Peer assessments are widely used by educational institutions to measure teamwork competence (Ohland et al., 2012). This assessment can assist in individual learning about patterns of expected behaviour for competence, help in reflections on results and contributions to teamwork, as well as feedback on competence development (Dominick, Reilly, & McGourty, 1997; Gueldenzoph & May, 2002; Mayo, Kakarika, Pastor, & Brutus, 2012).

Teamwork has many dimensions, demanding the collection of multiple information. Researchers developed and validated many teamwork models (e.g., Salas, Sims, & Burke, 2005) used as references for measurement. Measurement processes are easier when the collection processes are automated. The choice of teamwork models should give preference for validated teamwork models implemented by automated tools.

2.4.2 Teamwork evaluation consistency

Indicators quality about peer evaluations are obtained through the indicators: r_{wg} and AD_t, which measures teamwork evaluation consistency.

Scales used for peer assessments were built to produce similar teamwork evaluations about a given teammate performing a specific mission. These observations are expected to converge even better when behaviourally anchored scales are used. Meanwhile, when measurements focusing a single member from different observers present a high level of disagreement, the ability of observers to apply the scales as raters can be questioned. Quality of reliability between team members' observations can be assessed through the two statistical indicators mentioned.

The first indicator measures how close two or more members evaluate a third common teammate: the interrater agreement r_{wg} (James, Demaree, & Wolf, 1984). A second measure calculates how close a team member measures himself compared to the average of the evaluations made by her teammates: the total average deviation AD_t (Burke, Finkelstein, & Dusig, 1999).

The goal for the value of interrater agreement (r_{wg}) is 1.0 (maximum value). In this case, the deviation between members' observations is null and all assessment values coincide, indicating that teammates area using the same criterion to evaluate a colleague.

The goal for the total average deviation (AD_t) is 0.0 (minimum value). In this case, the deviation between the value of an auto-assessment and the assessments made by teammates in a same team are null, indicating that a team member evaluates himself in the same way that his colleagues do.

3 Implementing team coaching

The initiative at Insper was in the context of software projects developed by students during the final half of the second semester of the undergraduate Computer Science program, in the class "Agile Design and Effective Programming". This course requires students to work in teams, developing software that addresses the actual needs of real customers, who are Insper's partners for the course. The class was comprised of 28 students (4 women and 24 men) divided into six teams to deliver two software projects. Teams were grouped with students with similar academic performance as measured by their previous grades in the class.

3.1 Project characteristics

The first deliverable, Project 1, involved the proposal by the part of the group of an innovative software project. After a process of design thinking and identification the teams come up with varied ideas: budget managers, coding competitions, small vendor marketplaces and short-term jobs hiring boards. Teams had 3 weeks to develop their prototypes while taking 3 other classes. There were six teams of 4 or 5 students, the team was kept the same for both projects.

The next project was the Sprint at the end of the semester. It started with a challenge presented by a startup related to understanding their customer's behaviour and the conversion of users from free to premium. The scope of our student's project was loading data exported from their operations into an analytics dashboard and present useful analysis and visualizations to the client. This project had multiple lines of work, including data analytics, the design of a backend, the design of a front-end, a scrum master and a product owner. Teams were free to organize their tasks provided that the scrum master was maintained for the project. This project lasted 3 weeks during which students didn't have any classes, and it was assumed that they were devoted to the project full time. A video call with the client happened weekly, where results were presented, and project could be steered in the right direction.

The breadth of this project demanded strong planning, coordination, and communication by the team. A simple division of labour into submodules would not work well because there were dependencies and often pivoting ideas was necessary. For the most part of those 3 weeks all students were physically in the same environment, which facilitated interaction.

3.2 Coaching sessions

The teams underwent coaching sessions facilitated by two professional coaches who had completed rigorous training in coaching. The training required a minimum of 220 hours of education on both the practical and theoretical aspects of coaching, as well as 100 hours of hands-on coaching experience. Additionally, the coaches had undergone extensive practice in conflict mediation techniques. Experienced team coaches were hired from the job market exclusively to work in coaching sessions. They were not faculty members, and had never contacted Insper's students before.

Students worked in two sprints, bringing the opportunity to implement three coaching sessions of two hours following the schema suggested by Hackman & Wageman (2005). Each team received support from the same coach during the three sessions. Descriptions of the coaching sessions are:

- At the beginning of the first sprint ("Project 1"), coaches facilitated team members' alignment of goals and commitments. In this first session, each coach moderated team members' discussions to determine common goals in consensual mode and the strategy that they would adopt to accomplish these objectives. Each coach assisted respective teams in building social norms they agreed to follow during the team mission. Finally, the coaches stimulated team members to reflect on what and how they will act in case of failure of norms.
- At the end of the first sprint, coaches promoted reflection on team members about improving performance for the second sprint ("Sprint") based on results achieved during the first one and evaluated by the professors. In this second session, each coach supported the feedback between team members through dynamics based on peer-evaluation results and intermediate outcomes. This opportunity allowed students to learn how to give and receive feedback. Finally, the coach created an opportunity for team members to discuss an evaluation of the team as a whole.
- At the end of the second sprint ("Sprint"), coaches served to develop teamwork lessons learned for team members based on their performance during the two missions. In this last session, based on a new set of peer evaluations and the last outcome evaluation, the coach worked with team members to facilitate a discussion about their evolution during the entire mission. The coach asked the team to reflect about their teamwork learning during the complete mission, as a whole and as individuals.

Students prepare their participation on coaching sessions after receiving their sprint performance results from the teachers of the course, as well as having turned in their teammate and auto teamwork assessments, which are published and shared anonymously among team members. Quality of teamwork reflections is more effective when students receive both project performance and teamwork assessments. Students have information about outputs and processes on hand, making them reflect about their behaviours and consequences based on team goals and the perceptions of colleagues.

3.3 Peer evaluation tool

The initiative adopted a summative approach to students' evaluation because the purpose of peer-evaluation is to serve as an instrument to help students to collect teamwork observations.

CATME® was selected as the peer-evaluation tool. This instrument is built with behaviourally anchored scales into a robust platform adopted by more than a thousand schools. The CATME Peer Evaluation function makes available a set of five variables for measuring teamwork capacity through observation, psychometrically validated (Ohland et al., 2012). Authors (Ohland et al., 2012) created the tool with five variables, which resulted from the consolidation of 33 items obtained from exploratory and factor analysis. The five scales are Likert-type scales anchored by behaviour patterns:

- Contributing to the teams' work,
- Interacting with team members,
- Having relevant knowledge, skills, and abilities,
- Keeping the team on track, and
- Expecting quality.

Psychometric validation of the set of five CATME variables was carried out and published by Ohland et al. (2012).

3.4 Survey about the effect of coaching sessions

A survey was elaborated to capture the effect of coaching sessions perceived by students due to the coaching sessions at the end of the semester. Questions were aimed to collect students' perceptions about how they improved in the following aspects that are required by teamwork competency: self awareness about their personality, conscientiousness about how they relate with other colleagues, and whether these learnings were due to coaching sessions or not. These questions were made because the primary resource coaches use is to promote individual reflections, and its main purpose is to promote teamwork development. Questions helped to understand if the intended purpose was achieved according to the student's point of view.

The survey collected students' answers for four questions through a five-point Likert scale (totally disagree, partially disagree, do not agree nor disagree, partially agree, and totally agree):

- Q1: The dynamics of the coaching sessions helped me to get to know the characteristics of my personality.
- Q2: The dynamics of the coaching sessions helped me to understand how I behave in relationships with other members of my team.
- Q3: The dynamics of the coaching sessions help me to identify characteristics of my behaviour that I would like to change over time.
- Q4: The dynamics of the coaching sessions have already helped me to modify my behaviour in relation to other team members.

4 Results

4.1 Indicators for quality of observation

The initiative collected two set of observations with the CATME® tool: one at the end of the first project (Sprint 1), and a second set at the end of a second project (Sprint 2). Figure 1 shows the results of the two indicators calculated with the data collected. The two indicators (r_{wg} and AD_t) where averaged to summarize results. The interrater agreement was averaged between teams, while the total average deviation was averaged between individuals. The evolution of both indicators from the first to the second project exhibits the progress in time of the quality of students' assessments.

The average team interrater agreement ($\bar{r}_{wg}$) resulted in closer evaluations between team members when measuring a third one, improving from 0,37 to 0,51 from beginning to the end, informing a likely trend of each team member developing consciousness about a common reference for evaluating their colleagues.

The total average deviation ($\overline{AD_t}$) improved from 3,83 at the end of the first mission ("Project 1") to 3,50 after the second one ("Sprint"), exhibiting a likely trend of becoming closer to the evaluation that their respective teammates gave to them. The result requires a bigger sample to generate confirmation. However, it brings the chance that team members have acquired an improvement on auto awareness after the two projects.

Evolution of indicators between two projects

	$\bar{r}_{wg}$ (1)		$\overline{AD_t}$ (2)	
	Project 1	Sprint	Project 1	Sprint
Indicators	0.37	0.51	3.83	3.50
Teams	6	6		
Students			27	27

Notes. (1) Mean interrater agreement (2) Mean total average deviation
Indicators change from Project 1 to Sprint were not significant

Figure 1 – Evolution of indicators at the end of two sequential projects

4.2 Survey about the effect of coaching sessions

Fourteen students (50 % of sample) answered the survey. According to Figure 2, summing the positive answers (totally agree, and partially agree), the survey exhibited the majority of respondents recognizing the benefits of the initiative both in their awareness about their personality (71 %), awareness of their teamwork behaviours (93 %), consciousness of their knowledge about what behaviours they could improve (86 %), and the behaviours that they even have improved during the projects (79 %).

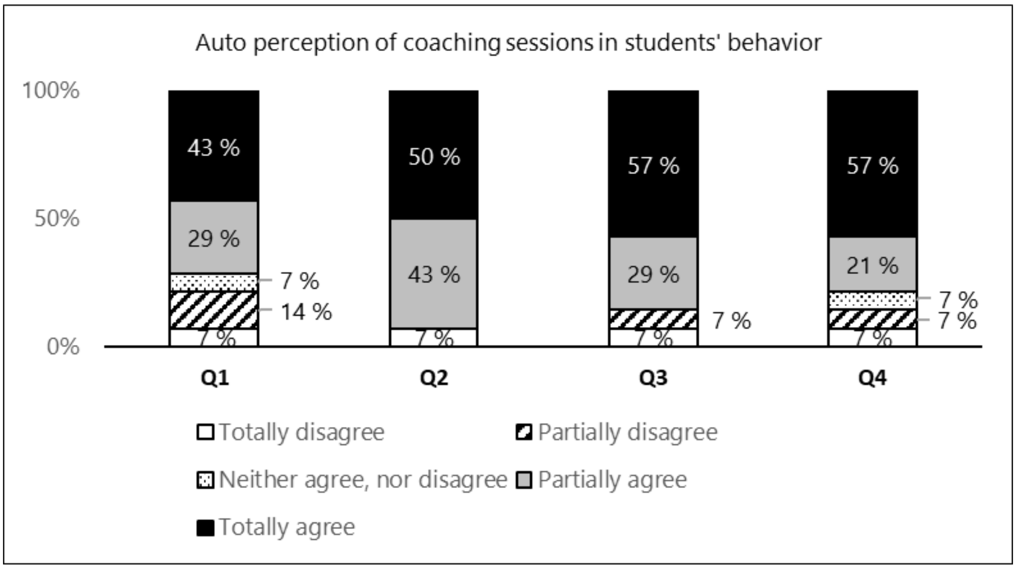

Figure 2 – Survey answers to four questions about students' perceptions after the whole initiative

5 Conclusions

Whereas results were not statistically significant, indicators exhibited that teammates, in average, improved their auto awareness about teamwork from the first to the second sprint (average AD_t decreases from 3,83 to 3,50), as well their assessments about other teamwork colleagues improved on quality (average r_{wg} improves from 0,37 to 0,51). Therefore, preliminary results endorse additional research to validate the proposition that team coaching sessions can improve teamwork learning by enhancing observation skills during project experiences.

Some questions are opened by the results. The first is whether the result was due only to the benefit of preserving team formation from first to the second mission or not; the influence of reflections brought by coaching sessions and peer evaluations should be isolated from the team experience to answer this question. A second investigation is whether the improvement of auto awareness is team specific, or it may also be applied to general level. That question opens the opportunity to extend the initiative with additional and different team formations to test if improvement in assessment competencies is independent of team members.

Additionally, the survey informed that a major part of the students perceived the initiative as positive in helping them to improve their teamwork competency. They recognize not only their awareness about the subject developed, but the experience also helped during the project to modify their own behaviour on how they relate with teammates.

6 References

Bowen, D. D. (1998). Team frames: The multiple realities of the team. *Journal of Management Education, 22*(1), 95-103.

Burke, M. J., Finkelstein, L. M., & Dusig, M. S. (1999). On average deviation indices for estimating interrater agreement. *Organizational Research Methods, 2*(1), 49-68.

Cohen, S. G., & Bailey, D. E. (1997). What makes teams work: Group effectiveness research from the shop floor to the executive suite. *Journal of management*, *23*(3), 239-290).

Dominick, P. G., Reilly, R. R., & McGourty, J. W. (1997). The effects of peer feedback on team member behavior. *Group & Organization Management, 22*(4), 508-520.

Dunne, E., & Prince, S. (1997). Higher education: Training students to work in teams. *Athens: European Association for Research on Learning and Instruction.*

Gueldenzoph, L. E., & May, G. L. (2002). Collaborative peer evaluation: Best practices for group member assessments. *Business Communication Quarterly, 65*(1), 9-20.

Hackman, J.R. and Wageman, R. (2005) 'A theory of team coaching', *Academy of Management Review, 30*(2), pp.269-287.

Harris, T. C., & Barnes‐Farrell, J. L. (1997). Components of Teamwork: Impact on Evaluations of Contributions to Work Team Effectiveness 1. *Journal of Applied Social Psychology*, 27(19), 1694-1715.

Hastings, R., & Pennington, W. (2019). Team Coaching: A thematic analysis of methods used by external coaches in a work domain. *International Journal of Evidence Based Coaching and Mentoring*, 17(2), 174-188.

Hertz-Lazarowitz, R. (1989). Cooperation and helping in the classroom: A contextual approach. *International Journal of Educational Research, 13*(1), 113-119.

James, L. R., Demaree, R. G., & Wolf, G. (1984). Estimating within-group interrater reliability with and without response bias. *Journal of applied psychology, 69*(1), 85.

Jones, R. J., Napiersky, U., & Lyubovnikova, J. (2019). Conceptualizing the distinctiveness of team coaching. *Journal of Managerial Psychology, 34*(2), 62-78.

Kolb, D. A. (2014). *Experiential learning: Experience as the source of learning and development*. FT press.

Kozlowski, S. W., & Ilgen, D. R. (2006). Enhancing the effectiveness of work groups and teams. *Psychological science in the public interest, 7*(3), 77-124.

Kozlowski, S. W. J.; Klein, K. J. (2000). A multilevel approach to theory and research in organizations: Contextual, temporal, and emergent processes. In Klein, K. J., Koslowski, S. W. J. (Eds.), *Multilevel Theory, Research and Methods in Organizations*, p. 3-90, San Francisco, CA: Jossey-Bass.

Levi, D., & Askay, D. A. (2020). *Group dynamics for teams*. Sage Publications.

Loughry, M. L., Ohland, M. W., & Woehr, D. J. (2014). Assessing teamwork skills for assurance of learning using CATME team tools. *Journal of Marketing Education, 36*(1), 5-19.

Mann, C. (2015). The 6th Ridler report: Strategic trends in the use of executive coaching. Retrieved on January, 26, 2020. Available at: http://www.associationforcoaching.com/media/uploads/6th_ridler_report_- _joint_icf,_ac_and_emcc_webinar,_december_2015_-_presentation_slides.pdf .

Mathieu, J. E.; Heffner, T. S., Goodwin, G. F., Canon-Bowers, J. A. & Salas, E. (2005). Scaling the quality of teammates' mental models: equifinality and normative comparisons. *Journal of Organizational Behavior*, v. 26, n. 1, p. 37-56.

Mayo, M., Kakarika, M., Pastor, J. C., & Brutus, S. (2012). Aligning or inflating your leadership self-image? A longitudinal study of responses to peer feedback in MBA teams. *Academy of Management Learning & Education, 11*(4), 631-652.

McGourty, J., & De Meuse, K. P. 2001. *The team developer: An assessment and skill building program*. Student guidebook. New York: John Wiley & Sons.

Michaelson, L., Peterson, T., Sweet, M., & Fukami, C. V. (2009). Building learning teams: The key to harnessing the power of small groups in management education. *The SAGE handbook of management learning, education and development*, 325-343.

Moran, L., Musselwhite, E., & Zenger, J. H. (1996). *Keeping teams on track: What to do when the going gets rough.* Irwin Professional Pub.

Ohland, M. W., Layton, R. A., Loughry, M. L., & Yuhasz, A. G. (2005). Effects of behavioral anchors on peer evaluation reliability. *Journal of Engineering Education, 94*(3), 319-326.

Ohland, M. W., Loughry, M. L., Woehr, D. J., Bullard, L. G., Felder, R. M., Finelli, C. J., ... & Schmucker, D. G. (2012). The comprehensive assessment of team member effectiveness: Development of a behaviourally anchored rating scale for self-and peer evaluation. *Academy of Management Learning & Education, 11*(4), 609-630.

Prichard, J. S.; Stratford, R. J.; Hardy, C, (2004). Training Students to work in teams: Why and How? University of SouthHampton.

Porter, G. (1993). Are we teaching people not to work in teams: Reflections on team based assignments in the college classroom. *CSWT Anniversary Proceedings,* 373-379. Denton, Texas: University of North Texas.

Rouse, W. B.; Cannon-Bowers, J. A.; Salas, E. (1992). The role of mental models. In *Team performance in complex systems. Systems, Man and Cybernetics*, IEEE Transactions on, v. 22, n. 6, p. 1296-1308.

Rosenstein, R. (1994). *The teamwork components model: An analysis using structural equation modeling*. Old Dominion University.

Salas, E., Sims, D. E., & Burke, C. S. (2005). Is there a "big five" in teamwork?. *Small group research, 36*(5), 555-599.

Shamir, B., Zakay, E., Breinin, E., & Popper, M. (1998). Correlates of charismatic leader behavior in military units: Subordinates' attitudes, unit characteristics, and superiors' appraisals of leader performance. *Academy of management journal, 41*(4), 387-409.

Sloman, S.. Fernbach, P. (2017). *The Knowledge Illusion – Why we never think alone*. New York, NY: Macmillan.

Sundstrom, E.; De Meuse, K. P.; Futrell, D. (1990). Work teams: Applications and effectiveness. *American psychologist*, v. 45, n. 2, p. 120.

Widdowson, L., Rochester, L., Barbour, P. J., & Hullinger, A. M. (2020). Bridging the Team Coaching Competency Gap: A review of the literature. *International Journal of Evidence Based Coaching & Mentoring, 18*(2).

Metaverse Workspaces for Active Learning – Brazilian Oil & Gas Company case

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Abstract

The digitization of the economy, already quite advanced before 2020, accelerated significantly during the pandemic. Restrictions on holding face-to-face educational events during this period stimulated the development of its virtual and hybrid versions, bringing new challenges to workforce skills development. This paper discusses the use of 3D virtual environments and Metaverse in carrying out workforce training events, including considerations about pre, during or post-event, from the knowledge management perspective and a SWOT based on a multidisciplinary approach. A Brazilian Oil & Gas Company case supports the discussion with lessons learned from three events involving 8,000 people and more than 104,000 man-hours of participation. The findings highlight the democratization of access to knowledge, the innovation´s effectiveness in knowledge management with 90% satisfaction among the participants and favourability of 74% regarding the capacity for interaction between the participants in active learning activities.

Keywords: Active Learning, Metaverse, Knowledge Management, Conferences, Immersive learning.

1 Introduction

The term "4.0" has been used to label the new paradigms achieved by this digital transformation on the economy sectors, such as Agriculture 4.0, Industry 4.0, Services 4.0 (Belk, Belanche, & Flavián, 2023) and, more broadly, Economy 4.0 (Łukasiński & Nigbor-Drożdż, 2022), characterizing an era of intense global digitalization of the economy. To be competitive in this digitized economy, it is necessary to develop new skills, as new technologies and processes require new knowledge for their adoption (Bühler, Jelinek, & Nübel, 2022).

A large part of the activities is being automated, replacing human posts with robots and many others being transformed by digital facilities, such as AI resources, for example. In this context, knowledge sharing is an important factor to facilitate the innovation process, and to support transition periods (Karuppiah, Sankaranarayanan, D'Adamo, & Ali, 2023; Ribeiro, Nakano, Muniz Jr, & Oliveira, 2022). Therefore, it is imperative that organizations take an effort to ensure smooth acquisition, sharing and utilization of knowledge between individuals and teams (Ngereja & Hussein, 2021). It's important to investigate key factors and enablers to facilitate knowledge creation and promote knowledge sharing among workers in this new economy. How blue collars engage in learning and knowledge sharing in order to develop new competencies and skills is also an opportunity for research (Ribeiro, Nakano, Muniz Jr, & Oliveira, 2022).

The covid-19 pandemic also added a new challenge to organizations during the period of social isolation: how to continue creating and sharing knowledge with a more distributed workforce? This challenge has accelerated the search for digital solutions in corporate education to support knowledge management in a hybrid work world, that is, with flexible working hours that combine face-to-face work with remote work. The pandemic period also initiated a great growth of interest in research on the digitization of education (Díaz-García, Montero-Navarro, Rodríguez-Sánchez, & Gallego-Losada, 2022). In this sense, also seeking new solutions on the basis of digital transformation, the area of education, especially higher and workforce training, has also been experimenting with the application of new technologies and strategies for sharing knowledge, coining education 4.0 (Bonfeld, Salter, Longmuir, Benson, & Adachi, 2020).

Education 4.0 is an emergent field, and no standard definition has yet to emerge, but it has been reacting to the use of disruptive technologies, the same as the basis of other economy 4.0 sectors, in education, enabling greater effectiveness in teaching-learning strategies. As developed economies move to mature stages of the fourth industrial revolution, the quality of education needs to keep up with the required technological changes brought about by the digital transformation created by these technologies (Shenkoya & Kim, 2023).

Although distance learning supported by video calls and resource sharing has been a widely used alternative, it is far from desirable in learner engagement, a new and innovative method is needed to immerse them in the learning process, so as to develop their higher order and critical thinking skills and numerous empirical studies have demonstrated the effectiveness of Virtual Reality (VR) technologies on learner immersion and learning outcomes (Wang, Yu, Bell, & Chu, 2022).

Among the applications of VR technologies in the learning process is the creation of immersive environments to promote learning, called edu-metaverses, with the differential of promoting greater contextualization and social collaboration, fundamental aspects for the creation and sharing of knowledge (Guo, Suo, Hu, & Duan, 2022; Ruwodo, Pinomaa, Vesisenaho, Ntinda, & Sutinen, 2022). The edu-metaverses has been explained as a kind of educational environment beyond reality, which has the immersion characteristics of the real world and the open and free characteristics of the virtual world (Zhong & Zheng, 2022). Edu-metaverses provides new possibilities for innovation in learning environments and resources, teaching forms, and educational content, and will promote profound changes in education and empower the future of education. Nonetheless, the theoretical support of the metaverse, the infrastructure construction of new technologies and ethical research still need to be further explored to move together toward a future of deep integration of technology and education (Zhong & Zheng, 2022).

In this exploration, the opinion of users is a relevant aspect for the adoption and evolution of the use of such environments, as well as for evaluating how they contribute to improving knowledge sharing and education in general (Ruwodo, Pinomaa, Vesisenaho, Ntinda, & Sutinen, 2022).

Some academic congresses have already taken place in 3D immersive environments like that (Wang, Yu, Bell, & Chu, 2022). Holding seminars is an example of knowledge management practice in organizations that also began to use this kind of solution. This paper discusses the use of 3D virtual environments and Edu-metaverses in carrying out workforce training events, as seminars events, with the aim of identifying strengths, weaknesses, challenges and opportunities for their use in corporate seminars from the company employee’s perspective.

2 Literature Review

Using Virtual Reality to solve the adult problem in higher education has been researched since 1995 and still going rapidly nowadays (Sunardi & Meyliana, 2022). Applications were initially more present in the implementation of virtual environments, such as laboratories for learning various topics, such as the laboratory for automation systems simulated experiment presented by Schaf, Paladini, & Pereira (2012) and the Virtual Laboratory for teaching Calculus presented in Tarouco, Gorziza, Correa, Amaral, & Muller (2013). In these works, the potential for collaboration provided by virtual reality was already highlighted.

With the technological evolution of 3D virtual environments, making the potential to simulate social relations in such environments more robust, the term metaverse began to be more used to name such environments.

Although it is still a concept under construction, the typology for metaverses, presented by Kshetri (2022), shows the evolution of the concept and classifies metaverses into four categories, depending on the degree of control that the user has over the environment and the interface technology (2D or 3D). Table 1 presents the four categories formed by the respective quadrants.

Table 1. Diverse metaverses: A typology and examples. Source:[11]

Decentralized economy based on cryptocurrencies ➡ 3D VR/AR content ⬇	No	Yes
No	[1] › 2D virtual meeting spaces (for example, Gather Town)	[2] › 2D Web3 games (for example, Reality Chain, Crypto Quest, Osiris[13])
Yes	[3] › 3D metaverses in which users are within confines of a centrally controlled environment (for example, Fortnite, Roblox, and Horizon Worlds)	[4] › 3D metaverses based on decentralized blockchains (for example, Decentraland and The Sandbox)

This typology of the metaverse can help us understand how different metaverses create value for users in many ways in relation to the importance given to different metaverse features. In physical worlds, for example, participants move fluidly from one conversation to another. A simple 2D metaverse, like cited at first quadrant, can improve this aspect by allowing people to interact more naturally (Kshetri, 2022).

The 3D metaverses bring the benefits of a more realistic manipulation of objective that provides greater potential for use in simulations such as experiences in virtual laboratories (Schaf, Paladini, & Pereira, 2012; Tarouco, Gorziza, Correa, Amaral, & Muller, 2013) and design of products and physical environments (Khansulivong, Wicha, & Temdee, 2022). Other benefits are enhanced motivation, effective communication, flexibility, time, and cost-effectiveness (Häfner, Dücker, Schlatt, & Ovtcharova, 2018). Some universities are creating their campus versions in centralized 3D metaverses, which are being called metaversity (Meta-University). For example, the University of California, Berkeley rebuilt its campus in the sandbox game Minecraft and held an online graduation ceremony. An international virtual campus was created to replicate the dynamics and design of the campuses of the University of California, San Diego (UCSD) in California, USA and Waseda University in Tokyo, Japan (Wang, Yu, Bell, & Chu, 2022).

This metaverse context it is possible to have spatial union, interactive presentations and collaboration work in real time. They can support several aspects of online classrooms with realistic senses, personalized teaching models, realistic 3D identities, interactive communication, and gamified learning (Chen, 2022). Decentralized metaverses are in the early stages of their development and are built on the foundations of blockchain technologies (Wilser, 2022). They are governed through a decentralized autonomous organization (DAO). Users can purchase portions of the environment, which can be used to build marketplaces and applications (Decentraland, 2022).

As long as the Digital Transformation is here to stay, probably the most promising aspects that are being studied, and will generate more scientific dialogue in the future, is the perception of the DT transformation of higher education by the different stakeholders involved in this change (managers, professors, administrative staff, students, employers, society as a whole...), as they hold very different points of view, but probably all of them are necessary to squeeze all the potential of this technological revolution (Díaz-García, Montero-Navarro, Rodríguez-Sánchez, Gallego-Losada, 2022).

The case study presented in this paper explores the holding of corporate seminars to knowledge-sharing, by the workers view, in immersive environments using a metaversity composed of a 3D immersive environment and a 2D centralized metaverse solution.

3 Methodology

This case study investigates the use of immersive environments and metaverses in knowledge sharing events from the participants' perspective. Three corporate seminars were held in a metaversity composed of centralized 3D and 2D metaverse environments, in a Brazilian Oil & Gas Company. Two questionnaires were applied to assess the satisfaction of the participants and the effectiveness of the experience.

The first questionnaire focused on evaluating the overall satisfaction of the participants and was composed of two questions:

1) How do you evaluate the virtual environment of this event? (5 points scale).

2) Describe the main highlights of this event and the aspects that need to be improved in the next edition (open question).

The second questionnaire focused on the capability of the environment, specifically the 2D metaverse component, regarding the communication and interaction characteristics needed in active learning practices. This second questionnaire consisted of 15 objective questions (Table 5) and 4 open-ended questions:

1) Highlight the main practical benefits perceived over other remote training solutions.

2) Highlight the main practical benefits perceived in relation to face-to-face teaching.

3) Highlight perceived limitations in relation to other teaching modalities.

4) Record here any additional considerations you find relevant.

The answers were analysed and significant analysis criteria were identified in the view of the participants. This investigation has performed the Strength-Weakness-Opportunity-Threat (SWOT) analysis to evaluate the use of the immersive experiences on sharing knowledge with active learning resources components.

3.1 Context of Study: Immersive sharing-knowledge events

The events were held in an immersive 3D navigation environment and complemented with a 2D metaverse for more interactive activities. They contemplated the realization of several keynotes and panels with the possibility of questions asked by the participants. The program was made up of external speakers, some international, and an internal speaker, sharing good practices implemented in the company. Figure 1 shows the Lobby and the Meeting Rooms Access of one of the events. The case included three events and a total of 8,448 participants and more than 104,000 man-hours of participation. Table 2 summarizes the main data of the events performed.

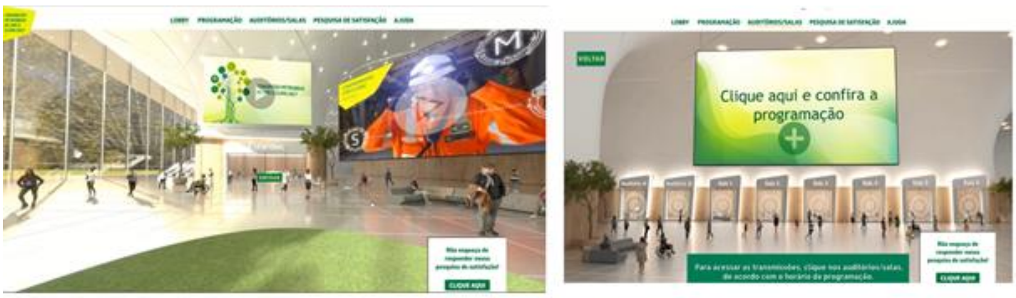

Figure 1. Lobby and Meeting Rooms Access. Source: Website of event (Author)

Table 2. Held Events.

Title	Year	Subject	Number of participants	Format
Event 1	2021	Health, Safety, Environment and Climate.	4181	Virtual
Event 2	2022	New Methodologies and Technologies for workforce Learning.	1718	Hybrid
Event 3	2022	Soft Skills.	2549	Virtual

All events had booths areas. Contents were made available in these areas in various formats for free exploration and channels of contact and interaction with exhibitors.

Participants were also able to participate in some gamified activities available in the environment. Debates and other active learning methodologies were used in a talk area and at mini-courses with a lot of interaction, using a 2D metaverse environment. The figure 3 illustrates a group dynamic held in a mini-course.

Figure 3. A group dynamic in 2D Metaverse Area.

4 Findings

As attendees form the main component of the experience, their feedback offers critical insights for conducting a SWOT analysis. The organization considered in this analysis was the metaversity where the events were held. Thus, strengths and weaknesses refer to metaversity aspects and opportunities and threats refer to other external issues that can impact the success of events held in such environments.

The answers were analysed and significant analysis criteria were identified in the view of the participants. These criteria were used to classify each item distributed in the SWOT matrix (Table 3).

Table 3. SWOT Analysis.

(Strengths)	(Weaknesses)
Availability: Availability of access to content and programming prior to the event. Increased access to post-event content. Possibility of accessing the contents for those who cannot participate during the event, both the contents that were transmitted synchronously and those made available asynchronously. Access: Wide possibility of participation, without restrictions due to limited physical space. Visual Quality: Visual quality of the 3D environment, allowing a feeling of immersion. Interactivity: Participant's freedom to explore contents and environments. The metaverse feature enabled direct and extended interaction with speakers and other attendees. Organization: Organization of contents, facilitating the identification of information of interest. Architecture: Arrangement of the rooms in the 3D environment. Usability: Ease of navigation through the platform.	Programming: Few resources in programming consultation. Publicity: Lack of resources integrated with other means of communication to promote better publicity of the event. Accessibility: Not having Libras in all communication situations (Synchronous and asynchronous content). Accessibility: Not having a high-quality simultaneous translation both into a foreign language and into Portuguese. Connectivity: There were some access difficulties for employees on board platforms. Interaction in lectures: Interaction with lecturers during lectures was restricted to chats. Delay: The contents of asynchronous streams were not available instantly. In some events they were made available a few days later.
(Opportunities)	(Threats)
Availability: Access at any time and without queues. Geographic Dispersion: Enabled participants from all regions of the company. Globalization: made possible the participation of many international speakers.	Disclosure: Little advance notice of events makes it difficult to reserve agendas for participation. Interaction: Lack of a communication channel with participants before the event. Focus: Some reported greater difficulty concentrating because they were not in an isolated physical environment for the event. It is easier to shift attention to other demands. Agenda: Difficulty prioritizing time at work to participate in events.

The SWOT analysis demonstrates that democratization of access to knowledge and collaboration, due to the high availability and ease of access are more significant strengths, whereas lack of an appropriate accessibility and competition of attention in digital with other demands of work are major challenges in the holding the events.

Table 4 presents the consolidation of the satisfaction assessment regarding the experience in immersive environments, based on the answers to the objective question. The evaluation scale used was from 1 to 5, where 1 represents a bad experience and 5 an excellent experience.

The general evaluation of the experience in the environment was favourable by 90% (grades 4 and 5). In the open questions, recommendations were reported for more intensive use of this resource in the next events, relating it to a greater capacity for interaction and active learning. Event 1, which took place every two years in face-to-face format, had a participation increase of 329%.

Table 4. Attendees' satisfaction.

	1 (Bad)	2 (Poor)	3 (Average)	4 (Good)	5 (Excellent)
Event 1	0	2%	6%	43%	50%
Event 2	0	3%	16%	31%	50%
Event 3	0	2%	3%	43%	52%
Total Averages	0	2%	8%	39%	51%

As for the sessions held in the 2D Metaverse with avatars, there was great demand, the vacancies were quickly exhausted, showing the interest by the new technology. Table 5 presents the consolidation of the participants' satisfaction assessment regarding the interactivity resources of the 2D metaverse component used for active dynamics.

Table 5. Metaverse 2D Component Evaluation.

Question	1 (Bad)	2 (Poor)	3 (Average)	4 (Good)	5 (Excellent)
Ability to see and hear the presenter/avatar.	1%	6%	10%	28%	54%
Ability to interact with the present/avatar.	4%	6%	12%	28%	49%
Ability to access shared content (videos and documents).	4%	6%	13%	33%	43%
Ability to see and hear the other participants.	3%	8%	14%	23%	53%
Ability to interact with other participants.	6%	5%	15%	21%	53%
Ability to gather in groups.	6%	4%	9%	28%	52%
Ability to move between groups.	6%	6%	10%	27%	51%
Ability to hold informal conversations.	8%	11%	9%	27%	45%
Ability to move through the spaces of the environment.	6%	4%	15%	28%	46%
Ability to understand the way of interaction with people and environments.	7%	4%	12%	31%	45%
Accessibility Features.	8%	9%	15%	27%	41%
Ability to simulate situations that occur in real physical spaces.	9%	3%	26%	26%	35%
Ability to promote informal learning: eg. Corridor and coffee conversations.	9%	11%	20%	27%	33%
Ability to perform group dynamics, such as World Coffe.	5%	5%	29%	23%	38%
Ability to hold events such as congresses and seminars.	9%	1%	27%	22%	40%

5 Conclusion

The virtual 3D immersive seminars presented in this case achieved high levels of satisfaction on the part of the participants regarding the digital format. The average satisfaction rating was 90%. The visual quality, the interactivity with content and participants, the architecture and ease of navigation in the environments, and especially the availability of access at any time, were highlighted as strengths perceived by the participants. One of the events had a 329% increase in the number of participants compared to the previous edition held in person. The sense of presence was also highlighted and perceived as a motivational factor, generating engagement in knowledge sharing.

In the active activities developed in the 2D metaverse, greater agility in grouping people and less time spent to gather participants in the same place were highlighted. Playfulness and interaction that were more spontaneous and closer to face-to-face were also mentioned. The favourability of 74% was verified regarding the capacity for interaction between the participants.

Among the weak points were the lack of customization in programming access, translations, and mainly the lack of more accessibility resources, such as the use of Libras. In addition to criteria related to the environment, the survey also highlighted some opportunities for threats arising from the adoption of this event format. Among the opportunities, greater ease of international participation was highlighted, favouring the sharing of knowledge globally and the optimization of time. But it was also highlighted that this flexibility can be a threat by making it difficult to prioritize the time for the event due to other demands in the workplace.

This work, however, was restricted to an analysis from the point of view of the participants. Complementary analyses from the point of view of speakers and organizers of the event are recommended for future research.

6 References

Belk, R. W., Belanche, D., & Flavián, C. (2023). Key concepts in artificial intelligence and technologies 4.0 in services. *Service Business Open Access*. Volume 17, Issue 1, Pages 1 - 9

Łukasiński, W., & Nigbor-Drożdż, A. (2022). STARTUP AND THE ECONOMY 4.0. International Journal for Quality Research. Open Access. Volume 16, Issue 3, Pages 749 - 766

Bühler, M. M., Jelinek, T., & Nübel, K. (2022). Training and Preparing Tomorrow's Workforce for the Fourth Industrial Revolution. *Education Sciences*. Volume 12, Issue 11 Article number 782.

Karuppiah, K., Sankaranarayanan, B., D'Adamo, I., & Ali, S. M. (2023). Evaluation of key factors for industry 4.0 technologies adoption in small and medium enterprises (SMEs): an emerging economy context. *Journal of Asia Business Studies,* 17:347–370.

Ribeiro, V. B., Nakano, D., Muniz, Jr. J., & Oliveira, R. B. (2022). Knowledge management and Industry 4.0: a critical analysis and future agenda. *Gestão & Produção* 29: e5222. http://doi.org/10.1590/1806-9649-2022v29e5222.

Ngereja, B. J., & Hussein, B. (2021). An examination of the preconditions of learning to facilitate innovation in digitalization projects: a project team members' perspective. *International Journal of Information Systems and Project Management* 9:23-41. http://dx.doi.org/10.12821/ijispm090202.

Díaz-García, V., Montero-Navarro, A., Rodríguez-Sánchez, J. L., & Gallego-Losada, R. (2022). Digitalization and Digital Transformation in Higher Education: A Bibliometric Analysis. *Front. Psychol* 13:7718.

Bonfeld, C.A., Salter, M., Longmuir, A., Benson, M., & Adachi, C. (2020). Transformation or evolution?: Education 4.0, teach- ing and learning in the digital age. *Higher Education Pedagogies* 5: 223–246. https://doi.org/10.1080/23752696. 2020.1816847

Shenkoya, T., & Kim, E. (2023). Sustainability in Higher Education: Digital Transformation of the Fourth Industrial Revolution and Its Impact on Open Knowledge. *Sustainability* (Switzerland)15: 2473.

Wang, M., Yu, H., Bell, Z., & Chu, X. (2022). Constructing an Edu-Metaverse Ecosystem: A New and Innovative Framework. *IEEE Transactions on Learning Technologies* 15:685-6961.

Guo, D., Suo, J., Hu, Q., & Duan, C. (2022). The Impact of Technology in Educational Resources: a Survey and New Perspectives. In: *Proceedings - 2022 International Conference on Culture-Oriented Science and Technology*, CoST 2022. pp 114 - 118.

Ruwodo, V., Pinomaa, A., Vesisenaho, M., Ntinda, M., & Sutinen, E. (2022). Enhancing Software Engineering Education in Africa through a Metaversity. *2022 IEEE Frontiers in Education Conference*, FIE 2022.

Zhong, J., & Zheng, Y. (2022). Empowering Future Education: Learning in the Edu-Metaverse. In: *International Symposium on Educational Technology, ISET 2022*, Hong Kong. pp 292 - 295.

Sunardi, H. A. N., & Meyliana, P. H. (2022). Discipline, Impact, And Challenges Of Virtual Reality In Higher Education: A Systematic Literature Review. In: *7th International Conference on Information Management and Technology,* ICIMTech 2022.

Schaf, F. M., Paladini, S., & Pereira, C. E. (2012). 3D AutoSysLab prototype: A social, immersive and mixed reality approach for collaborative learning environments. *Engineering Education Conference*, EDUCON 2012.

Tarouco, L., Gorziza, B., Correa, Y., Amaral, E. M. H. , & Muller, T. (2013). Virtual laboratory for teaching Calculus: An immersive experience. In: IEEE Global Engineering Education Conference, EDUCON, art. no. 6530195. pp 774-781.

Kshetri, N. (2022). A Typology of Metaverses. *IEEE Computer*. pp150-155.

Khansulivong, C., Wicha, S., & Temdee, P. (2022). Adaptive of New Technology for Agriculture Online Learning by Metaverse: A Case Study in Faculty of Agriculture, National University of Laos. 7th International Conference on Digital Arts, Media and Technology, DAMT 2022 and 5th ECTI Northern Section Conference on Electrical, Electronics, *Computer and Telecommunications Engineering*, NCON 2022. Pages 428 - 432

Häfner, P., Dücker, J., Schlatt, C., Ovtcharova, J. (2018). Decision support method for using virtual reality in education based on a cost-benefitanalysis. In: 4th Int. Conf. Virtual Augment. *Real. Educ*. VARE 2018. pp 103.

Chen, Z. (2022). Exploring the application scenarios and issues facing Metaverse technology in education, *Interactive Learning*

Wilser, J. (2022). The people of Decentraland will greet you now: Decentraland is a little like Second Life, but built on a blockchain. Meet the folks making a strange virtual world a reality." CoinDesk. Accessed: Aug.30, 2022. [Online]. Available: https://www.coindesk.com/markets/2020/06/25/the-people-of-decentraland-will-greet-you-now/

Decentraland (2022). A virtual world built on Ethereum." Gemini. Accessed: Aug. 30, 2022. [Online]. Available: https://www.gemini.com/cryptopedia/

ICT tools use in the scope of education in Engineering: a systematic review

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Abstract

Information and communications technology (ICT) has an enormous impact on defining what the classroom and the learning process are in the 21st century. It became necessary to include these resources in the educational environment to improve and make the educational process more efficient. The objective of this article is to identify the ICT educational tools developed, associated, and applied in the field of higher engineering education (EE). Therefore, a Systematic Literature Review (SLR) is performed to consider the different tools present in interactive learning environments and the context in which they are applied. The research questions developed through the PICO method are: What ICTs (interactive tools) have been developed or found to enrich the different smart learning environments and engage active learning in engineering in the past three years? This is then deconstructed in sub-research investigation questions: Q1: How many ICT tools with application in Higher Education for Engineering have been developed or applied in the last three years? Q2: Which are the areas of application or subjects in which its use is appropriate? Q3: What role do the ICT tools perform in the educational process or in the different teaching-learning environments? The SLR allowed to identify the areas for further exploration, grouping them together and explaining the purpose of the different tools and their application. VOSviewer was used to visually analyse network maps of co-occurrence of authors keywords, as well as others that prove to be decisive in characterizing the methodological approach to teaching and in the categorization of tools. Active learning classrooms are now and, in the future, the key point to the evolution of teaching and learning. Its determinant to understand what is currently being developed in this domain for more efficient and fastest adaptation of these valuable resources.

Keywords: ICT; Active Learning; Engineering Education; Interactive tool.

1 Introduction

Information and communication technology (ICT) is considered, nowadays, critical to the quotidian activities, success of companies and a good ally of education (Chandra & Fisher, 2009). Interactive and communicative content can improve the quality of education, transforming learning into an exciting and productive process (Palioura & Dimoulas, 2022). Education must be adaptable to the effective context and because of the conceptualization of the present reality, the educational process currently includes criteria such as multidisciplinary, intradisciplinary and cross-discipline approach (Sodikin, 2017).

The growing awareness of the need for technological innovation is now also a priority for engineering education, with the acquisition of knowledge and development of skills becoming more dynamic through diversified educational methods, the traditional approaches become less inefficient in today's society (Mayer, 2003). For that, it is necessary to adapt and develop resources to engineering, including a multidisciplinary approach that involves the different content of areas related to each concrete study program, to facilitating the development of teachers' technological and pedagogical content too (Heulingn & Wild, 2021).

The potential of digital technologies is distinguished by the cognitive stimulus provided to students (Batyrkhanov et al., 2022), which can constitute learning, research, communication, collaboration, construction, expression and even evaluation content (Zhu et al., 2016).

2 Literature Review

This chapter presents a review of the main concepts related to the theme, including the definition and aim of ICT tools and active learning.

2.1 ICT tools

ICT tools are related to who and what students use, acquire and adapt using technology. Digital competencies, digital literacy, information and computing literacy, internet skills, and ICT competencies and even 21st century competencies are concepts related and directed towards digitization and the use of ICT tools (Ainley et al., 2016; Hatlevik & Christophersen, 2013; van Laar et al., 2017).

It was verified that the ICT definition depends on the enormous number of concepts related to values, attitudes, and knowledge of digital technology, which originated multiple definitions that later support these concepts. The advancement and availability of technological devices led the specialists to agree that the implementation of ICT literacy (students´ use of digital and communication tools) changed (Erstad, 2006).

In the European framework for digital competencies, a more detailed definition declares it as a "confident, critical, and creative use of ICT to achieve goals related to work, employability, learning, leisure, inclusion and/or participation in society" (Ferrari et al., 2013). More recently Sumaimi and Susilawati (2021), affirmed that ICT tools are a "combination of technological devices and resources, which are used to manipulate and connect information. ICT is currently a major player in the education system, bridging forms of knowledge and literacy, the intersection between places of study, homes, schools, workplaces, and communities."

In the scope of the different ways to define the concept, it is clear that ICT tools are related to information and communication and this conceptual expansion is related to the extension, development, and involvement of the different ways to include ICT in the quotidian and inclusive in the aim of education.

2.2 Active Learning

Active Learning is defined by Prince (2004) as "adopting instructional practices that engage students in the learning process". Different methods implemented in the scope of active learning intends to provide a dynamic and effective way to assimilate knowledge making this approach more efficient than the traditional, improving conceptual learning. Felder et al., (2000) show that the following eight methos are intrinsically connected with engineering education engagement: use instructional objectives, reveal the material is relevant, teach inductively, balance concrete and abstract information, use active learning, use cooperative group learning, make fair test challenging and show concern about student learning. Active learning involves different methods (flipped classes, cooperative group learning, panels, debates, quiz shows, service learning, PBL, among others) but for implementation of this type of learning is essential to adopt technologies, especially nowadays, in the classroom or in the learning environment.

Smart learning environments or smart classrooms are supported by technology and digital devices and aims to reach all students improving student-teacher interaction (Mikulecký, 2012), involving students, instructors or an instructional system, depending on the settings of learning and support staff that can be designers or technical specialists being necessary the inclusion of class´s culture, course, institution and community (Spector, 2014).

Smart classroom empowers smart education (Uskov et al., 2015) that allows flexibility learning related to time and place (Zhu et al., 2016) allied with the appropriate pedagogical approaches, strategies categories for studying, and the employment of ICT tools (Venkatesh et al., 2014).

3 Research Methodology

To achieve the research purpose, firstly we consider the PICO (Patient or Problem, Intervention, Comparison, Outcome/s) method, that helps to define the aim of the search based on critical questions, as in this case (Akobeng, 2005). Afterwards, a Systematic Literature Review (SLR) was carried out, based on The Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA; Page et al., 2021). Finally, the VOSviewer (version 1.6.16), a software tool that supports qualitative analyses, was used helping the bibliometrics analysis namely the co-occurrence analyze of keywords visually (van EckNees & Waltman, 2019).

Related to PICO the problem or population that is fundamental for this research is the higher education community. In the scope of the intervention, it is presented the problem of developed ICT tools in the final year and after Covid-19. One of the objectives of this research is to compare the tools developed in the scope of the different curricular areas of engineering. Hence, the outcome that is intended to achieve with this research is to associate the different tools found with the SLR and with the different areas or curricular unities (CU) of engineering. The main research question is: Which are the ICTs (interactive tools) developed or found for enrich the different smart learning environments and engage the active learning in engineering in the past three years? This is deconstructed in the tree sub-research questions: Q1: How many ICT tools with application in Higher Education for Engineering have been developed or applied in the last three years? Q2: Which are the areas of application or subjects in which its use is appropriate? Q3: What role do the ICT tools perform in the educational process or in the different teaching-learning environments?

The subsequent flow diagram of the results obtained in the different application stages of the PRISMA method from 2020 is shown in Figure 1.

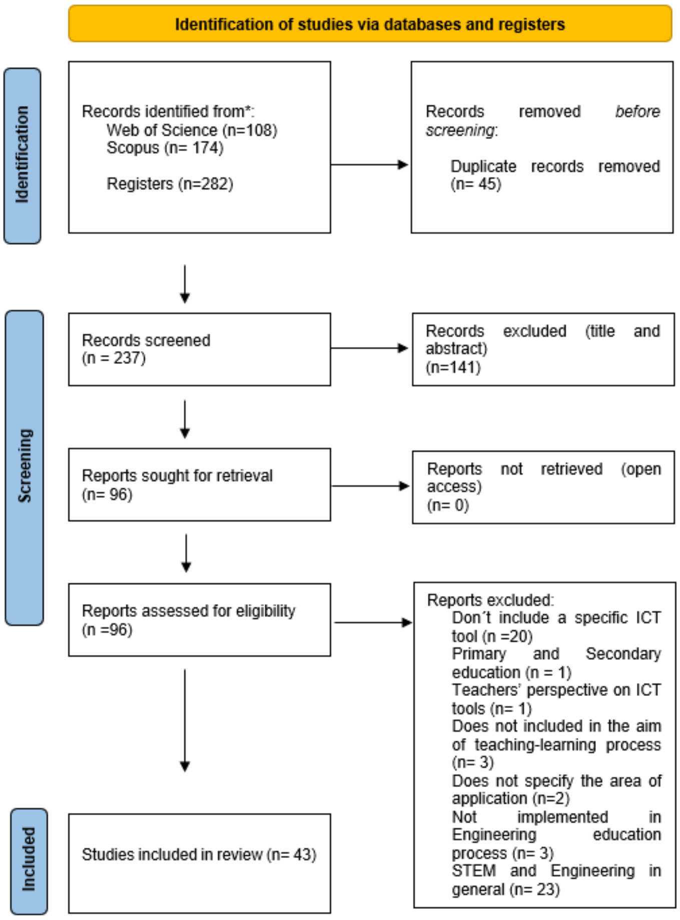

Figure 1: Application scheme of the PRISMA method (Page et al., 2021)

This research covered a set of 2 global databases (Web of Science and Scopus), from January 2020 to February 2023. The following string: "((("smart learning environment*") OR ("active learning") OR ("teaching") OR ("learning")) AND (("interactive tool") OR ("ict")) AND (("engineering") OR ("engenharia")))" was used, considering title or abstract or author keywords. Initially, due the large number of results in WoS (n=1, 685) and Scopus (n= 2,604) was applied the language filter (only English or Portuguese papers) and exclude all the results that do not have open access on either database.

An analysis of the selected articles (n=43) was, afterwards, performed. With the reading, it was possible to retain the included tools, organizing them by the area of engineering to which they belong, and an analysis was also made of their purpose and use in the teaching context, as shown in Table 1.
This analysis allowed to understand that tools are related to certain teaching methodologies approaches which leaves us to believe that they are developed for reinforcing active and practical learning.

4 Discussion

For better understanding and description of the main areas, concepts and focus of investigation the software VOSViewer was used to visually analyze the network maps of co-occurrence of keywords. The analysis was performed based on the keywords identified by the authors of the scientific articles. A total of 218 keywords were considered, being that all keywords appeared at least once and seven appeared at least three times. Figure 2 and 3 showed the overlay and network maps of keywords co-occurrence, respectively. Of the 218 keywords, only 125 are connected to each other. The size of circles represents the occurrence of a keyword, the thickness of the connection line shows the proximity of relationship between two keywords.

Figure 2 shows that, apparently, the emerging of virtual laboratories has a strong relation with chemical engineering (Martin-Villalba & Urquia, 2022), but this concept is also relevant in other areas such as electrical, environmental and maintenance engineering as identified during the SLR (Dong et al., 2020; Guo et al., 2022; Kans et al., 2020). It is also important to highlight subject areas as "computational fluid dynamics" (CFD) and "backtracking" by the relationship maintained in the different year (Gajbhiye et al., 2020; Seddighi et al., 2020; Solmaz & Van Gerven, 2022). "Adaptation" is a word that is commonly used not only in the context of learning-teaching methodologies but also of tools, a reaction possibly triggered by the experience gained with the pandemic and the need to adapt and digitize educational resources. In contrast "covid-19", "blended learning" and "moodle" are concepts that have been explored for a longer time, in the wake of the post-pandemic. The dimensions and behaviours of "engineering education" and "higher education" seem to follow a natural path as these are terms whose functions remain intact over time Over time, the preferred teaching strategies and tools evolve, as a result of innovation and improvements made in the teaching-learning process, as can be seen in the cases of "blended learning" of "moodle", these are more associated with the years 2020- 21 and more recently "online teaching", "gamification" and "adaptation" in a more recent era, as well as in the field of technological tools, "backtracking", "virtual laboratories", "visualization" are starting to be highlighted. associated with 2022, thus also contributing to the development of active learning.

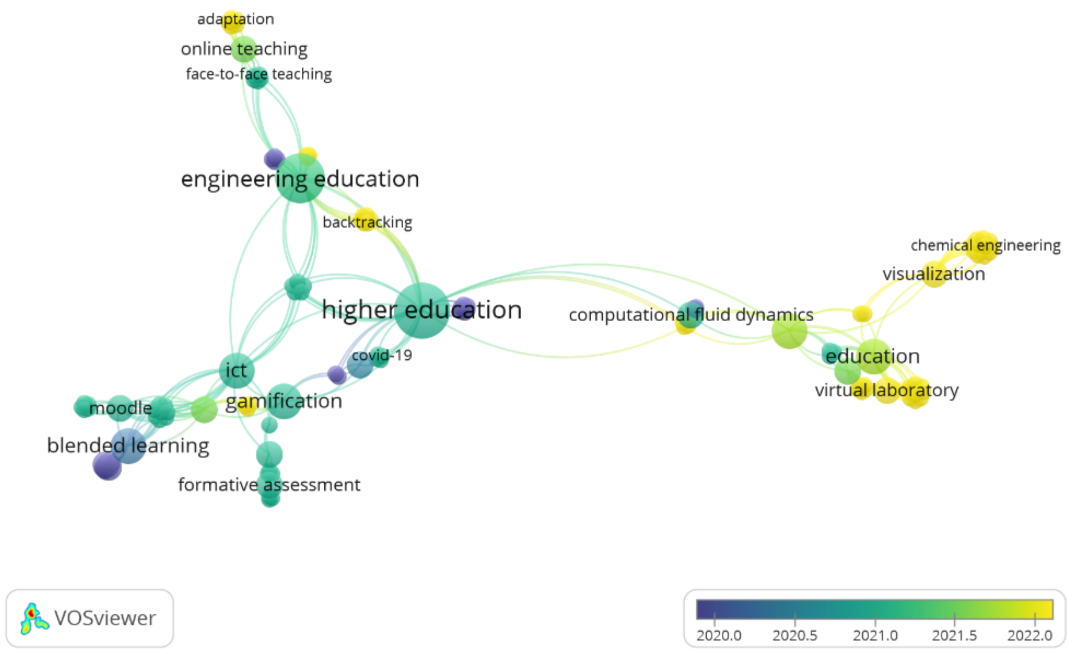

Figure 2: Overlay map visualization of keywords over the three years under analysis

Table 1. SLR articles analysis.

Areas	Articles	Tools	Aim of the tools
Computer Engineering	(Bhamre & Jagtap, 2021)	ICT Tool MKCL SuperCampus	The software application gives a real-time statistical result to the teacher related to answers given by students during the class.
	(Mora et al., 2020)	Learning web-platform	Peer review is evaluated and monitored by the web platform.
	(Nasralla, 2022)	ICTs for backtracking learning	This approach is illustrated with the n-queens problem (tool) and the purpose is for students graphically observe the execution step-by-step of backtracking algorithms.
	(Nadeem et al., 2022)	AR4FSM mobile application	With this app students can learn about finite-state machine (FSM) concepts from lectures, tutorials, and practical hands-on experience combined with a commercial timing simulation tool.
	(Pertegal-Felices et al., 2020)	Kahoot tool for sustainable education	This gamification approach through Kahoot shows an easy way of formative assessment in this case, on this case in Computer Engineering.
	(Pratibha et al., 2021)	Flipped mode of learning using the Learning Management System ICTs	This study includes MOODLE for virtual learning with the Learner's Centric MOOCs (LCM). LCM model is implemented through LMS (moodle platform) and this is to assuring the increase of effective Feedback and Assessment. This also includes video format and quizzes.
	(Chacon et al., 2021)	JavaScript Simulations (EJsS)	Easy JavaScript Simulations (EJsS) is an open-source tool that allows those with limited programming experience to straightforwardly bundle an interactive computer science or engineer simulation in an HTML+ JavaScript webpage.
	(Rahman et al., 2021)	AOJ system (course) and ALDS (course) tools	This can be useful for education, educational data mining, data analytics, and behaviour analysis. OJs have significant importance because conduct programming practices, competitions, assignments, and tests.
	(Seddighi et al., 2020)	Python (Jupyter) Notebook	This tool is used in Computational Fluid Dynamics (CFD) and combined with an industry-standard package.
Program / Software Engineering	(Petchamé et al., 2021)	La Salle URL Smart Classroom	SC uses a Sound system, Image System, Smart Board and Software to connect with off-campus students.
	(Farah et al., 2022)	Chatbot- Lint Bot	Online learning application that simulates the code review features available on social coding platforms and allows

Areas	Articles	Tools	Aim of the tools
			instructors to interact with students using an online learning environment.
	(Chikurtev et al., 2021)	Software tools for robots and sensors	Software tools and applications for producing several digital resources with applications in robotics are presented: Gazebo, Robot Operating System, Arduino. The process and the technologies used to build a digital resource (simulation model) through a Gazebo simulator for working with robots and sensors are described in this approach.
Mechanical /Control Engineering	(Lampón et al., 2022)	Tool using Sysquake	This tool was used in the master of control engineering to facilitate the study and learning of control systems.
	(Pando Cerra et al., 2023)	Mechanical Engineering Computer-aided design (CAD) tools using Problem-based learning methodology (PBL)	This approach allows students, using PBL and a new interactive tool called TrainCAD, the self-assessment of 2D-CAD models designed in AutoCAD.
	(Becattini et al., 2020)	E-learning platform for PBL	In this PBL was used, besides the e-platform the successive tools: WhatsApp, (slack.com), Trello (trello.com), Adobe Connect, OwnCloud repository, CAD tools, 3D models, such as GrabCAD.com and traceparts.com and Google Docs.
	(Bhamre et al., 2021)	MKCL SuperCampus	MKCL SuperCampus, was used to pose questions and to track real-time individual performance in the classroom.
	(Horvat et al., 2021)	ICTs for PBL implementation	In this article the tools used were Adobe Connect (Meetings, virtual brainstorming); Moodle (Communication with a coach, Information about the process and ICTs); OwnCloud (Storing files); MS Excel (Gantt chart); Trello (Task management); Miro (Problem framing, Functional decomposition, Idea generation); Espacenet (Patent landscaping); MS Word (Agenda, meeting minutes) and CAD/CAE/PDM (CAD modelling, analysis, data management). Student teams also used: video WhatsApp and email, Google Drive, Excel and Google Spreadsheet. Related to taskwork: ResearchGate; physical effects (e.g. productioninspiration.com); nature-inspired solutions (e.g. asknature.org); Google Forms; (draw.io); enabling collaborative work (e.g. MS Visio, MS Word); CAD tools (e.g. SolidWorks, AutoCAD, Autodesk Fusion 360); CAD models (e.g. GrabCAD, Traceparts) or to vote while making decisions related to various design aspects (e.g. easypolls.net); a tool for making videos (e.g. Adobe Premiere) and Google Docs.
Chemical Engineering	(Martin-Villalba & Urquia, 2022)	Collaborative virtual laboratory	Modelica library is used in this paper, because this tool can facilitate the implementation of collaborative virtual labs using only the Modelica language and this can promote the collaborative learning.
	(Solmaz & Van Gerven, 2022)	CFD simulation tool available for laptop and phone	This work presents a versatile development methodology to implement interactive CFD simulations with cross-platform environments such as desktop and virtual reality applications. Some of the tools identified are laptop using Ubuntu 14 OS, OpenFOAM v6 and COMSOL v5.6, mixerVessel2D tutorial, k-epsilon turbulence model was used to model fluid flow with 2D and steady-state arrangements and a 3D transient simulation.
	(Romero et al., 2021)	Moodle and Socrative	This article shows the advantages of Moodle and Socrative use in lectures.
	(Gajbhiye et al., 2020)	CFD tool	CFD is useful to understand students to implement modern mathematical tools as well as evaluate standard protocols followed in the industries. In this case, students use the interface of ANSYS Design Modeler and Fluent through and hands-on training and simulations have been carried out.

Areas	Articles	Tools	Aim of the tools
Mathematics Engineering	(Sri Vinodhini et al., 2021)	Smart Board using ICTs	Smart Board approach in formative assessment including ICT tools as Think Pair Share, Plickers cards, Polls for formative assessment.
	(Illanes et al., 2022)	Leaning process for calculus course using ICTs	The ICTs used besides the traditional ones (used for geometry), in the computer configuration the student had a notebook, cell phone or tablet, internet, GeoGebra (free version), QR code, educational videos, and applets. The language and procedures are of a graphic, geometric, and descriptive type. In the case of algebraic configuration, they had all of that and an educational software such as Symbolab (free version) and Wolfram Alpha (free version).
	(Parody et al., 2022)	Classcraft tool	This tool is supported by a digital platform and a mobile application that has been developed to answer teachers' classroom management needs and is aim is to enhance the interest of students helping in the development of critical thinking, communication, collaboration, and creativity.
Electrical Engineering	(Valiente et al., 2021)	Tools used for "Machines and Mechanisms Theory" subjects	The aim of this article was to collect the following tools used for the teaching/learning process: Google Suit, Google Hangouts (chat outlook) and Google Groups (forum outlook) were chosen to arrange half of the students in a test group and for practical classes different simulation software's were used, but mostly, AutoCAD and Matlab.
	(Daineko et al., 2022)	Digital Educational Platform	To improve and promote remote access the aim of this platform give access to educational materials and can monitor the level of student's performance too in the aim of the study of modern Ultra high frequency (UHF) and extremely high frequency (EHF) radio systems. Includes a database of collected laboratory results and the list of virtual labs that are part of the educational platform, as well as devices and measuring instruments used in the virtual lab (vector network analyzer ZVA-40; vector network analyzer E8363B PNA Network Analyzer; digital oscilloscope RTC1000; spectrum analyzer FPC1500). Also, the signal generator SMC 100A can be used in this context. The remote access implemented uses Unity 3D.
	(Obukhova et al., 2020)	ICT tools for Blended learning	The tools applied in this methodology for electrical engineering were Skype, Viber, WhatsApp and the capabilities available on the internet.
	(Dong et al., 2020)	Online Laboratory	This paper´s objective is to apply online lessons with hardware, software and ICT platforms including the flipped learning methodology.
Manufacturing Engineering	(Mahmood et al., 2021)	Virtual Learning Factory Toolkit (VLFT)	This article shows a set of digital tools operated in production management with engineering education. The tools included are Java Modelling Tools (JMT), OntoGui (GUI), Unity3D, VEB.js (Virtual Environment based on Babylon.js) and ApertusVR-based applications.
Automotive Engineering	(Hernández-Chávez et al., 2021)	Virtual Reality Tool	In the scope of automotive systems engineering was developed a tool to use as an immersive virtual learning strategy for Oculus Rift S Virtual Reality glasses and through Leap Motion Controller™ infrared sensors- VR that allows students to understand the operation of the four-stroke engine through animation and the assembly and disassembly of its main pieces.
Environmental Engineering	(Roundy et al., 2022)	Web-based platform (HydroLearn)	Use of the platform (HydroLearn) including Jupyter Notebooks and Google Collabs. This approach also includes using problem-based situations for better understanding of climate and the hydrologic cycle.
	(Galustyan et al., 2020)	ICT tools for Blended Learning	The tools used were Learning management systems (Moodle, Edmodo). Tools for creating and publishing content and training objects (1C test designer). Tools for communication and feedback (Vebinar.ru, Skype, Google Chat.). Tools for collaboration (Google Docs). Tools for creating communities (social network Facebook). Tools for planning educational activities (electronic journals).

Areas	Articles	Tools	Aim of the tools
	(Guo et al., 2022)	Web-based virtual laboratory on microgrids	This laboratory is multidisciplinary topics and include pedagogical material about renewable energy, power electronics, power systems, control, and communication. The virtual laboratory was developed using NI LabVIEW, Microsoft. Net Core, and MATLAB/Simulink.
Industrial Management Engineering	(Salah et al., 2020)	Tools for 4.0 industry	The teaching and training methodology used in this paper is inspired by Jungmann's research cycle, synchronized with Kolb's learning cycle. The tools included 3D printing, Autocad designs and worked on CATIA software required for the 3D printer, conveyor loop system from the L loop to the desired O loop and e-Cockpit software configured the WAGO PFC.
	(Moreno & Bartolomé, 2021)	SRPs and Q–A maps	This combination of methodology (SRP) and tool Q-A maps (using posteriorly internet) was used for teaching in Industrial Management and the aim is to improve web-based inquiry learning.
	(Krajčovič et al., 2022)	VR for workplace	This tool uses VR for workplace analysis and optimization. In this approach, authors also included a 3D game engine using C# programming language.
Quality Engineering	(Unzueta & Eguren, 2021)	ICTs for statistic subjects using blended learning methodology	Statistical analysis has a unique place in Quality Engineering. Tools mentioned: Moodle platform; Excel simulator; SIPOC tool; Ishikawa, histograms, doing-tools (ANOVA, factorial design-2k, fractional factorial design-2k-p, t-test and regression), using one simulator to obtain the necessary data from the injection process.
Graphic Engineering	(Veide et al., 2020)	Interactive and Animated Drawing Teaching- DIAD Tools	These tools are used with the aim of graphical engineering and include educational videos on topics of engineering graphics and descriptive geometry.
	(Vergara et al., 2021)	Interactive Virtual Platform-IVP	This tool aims are to increase students' spatial vision skills while learning industrial, for radiographic inspection. Other tools included were three-dimensional model, two-dimensional drawings, Microsoft Word drawing tools, Autodesk AutoCAD, BFD, Autodesk 3DS Max and Epic Unreal Engine 4 (UE4).
Maintenance engineering	(Kans et al., 2020)	Remote Laboratory	The ICT follows MIMOSA CRIS and OSA-CBM standards that allow remote connection with distant students and a test rig, being possible to perform condition monitoring, diagnostic and prognostic.
Civil Engineering	(Conesa, 2022)	ICT resources for online environment	This online environment is used for getting knowledge different aspects of ports in Europe and uses documentaries, video reports and interactive web resources.
Telecommunications engineering	(García-Sánchez & Luján-García, 2020)	MACbioIDi glossary	The aim of the project mentioned on this article is to create a collaborative bilingual, English-Spanish glossary and the tools used for accomplishing this aim were GitHub, Building 3D Slicer, Python, Python Numpy, Matplotlib, QT framework and VTK.
Power Engineering	(Haidar et al., 2021)	METF platform w/simulation tool	Application of PBL methodology using METF-based graphic simulation environment as an approach to teaching SG-related subjects.

Figure 3 allows the identification of four clusters, based on the keywords analysis, identified by different colors (green, red, blue and yellow) and to conceptualize the main conclusions obtained from the analysis of the articles, it is possible to highlight that the concepts "higher education" and "engineering education" have a solid prevalence, also because they are key concepts used in the research (green cluster). However, "education", "covid-19", "face-to-face teaching" and in opposition "emergency remote teaching" are words that may constitute a second plane of relevance in terms of frequency of use. Though, as previously noted, "chemical engineering" has a prominent place, with "virtual laboratories" being the tools with the greatest focus on development (red cluster). Curiously, here it is possible to observe that, "formative assessment" is heavily used and as verified in SLR, this evaluation method is often associated with the use of "gamification". The same happens with "Moodle" and "blended learning", the former being a prestigious tool for managing the educational process (yellow).

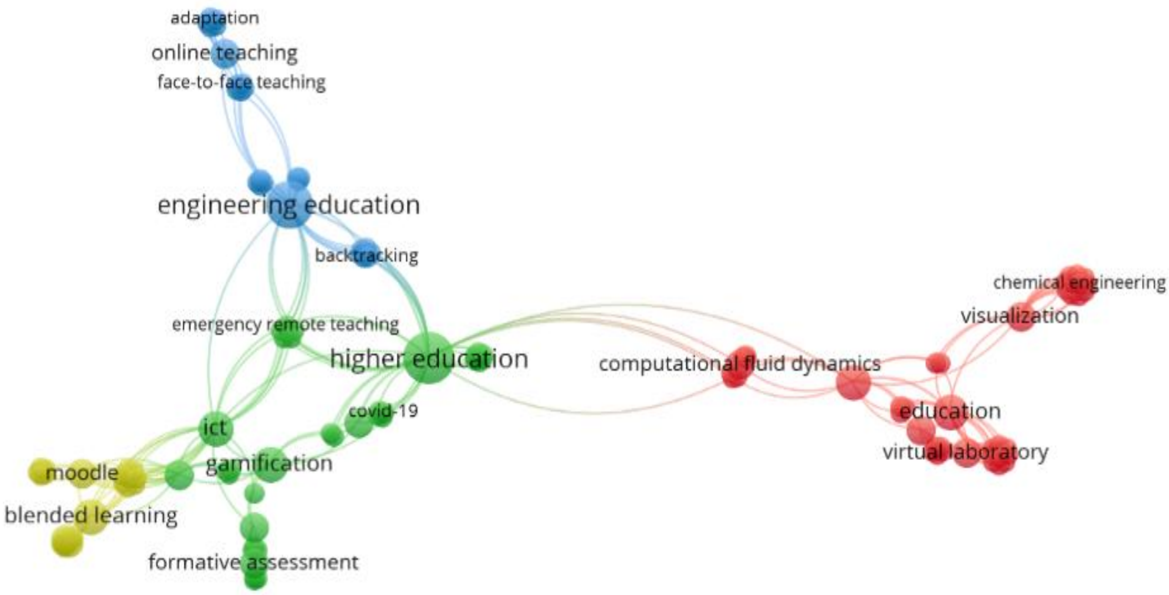

Figure 3: Most relevant keywords

5 Conclusions and Future Work

This paper reviews the use of ICT in the different fields of Engineering in the scope of higher education. This research can provide useful and valuable descriptions of technologies that could constitute the concept of the contemporaneous educational and learning processes in engineering higher education utilized in the context of smart learning environments.

With the SLR analysis it is possible to conclude that most of the tools are related to computer and chemical engineering and a large part are simulation tools. There is also an adaptation of existing tools and even use and conciliation of them with more recent ones.

The use of the bibliometric VOSviewer visualization software enabled to confirm a relation between the authors´ keywords that reveal a preponderant role in "formative assessment", "blended learning" "online teaching" e "virtual laboratory" in higher engineering education.

With the concern of making teaching accessible but also dynamic for greater assimilation of concepts, the creation and adaptation of tools turns was necessary. These tools allied with active teaching methodologies provide a significant and effective development of skills and competences in students.

Future work includes to understand how certain tools are suitable or not for certain teaching methodologies, establishing starting points for a greater and more effective construction and adaptation of resources in higher education, allowing effective development and preparation of students' skills for the labour market.

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6 References

Ainley, J., Schulz, W., & Fraillon, J. (2016). A global measure of digital and ICT literacy skills. In *Education for people and planet: Creating sustainable futures for all*.

Akobeng, A. K. (2005). Principles of evidence based medicine. *Archives of Disease in Childhood*, *90*(8), 837–840. https://doi.org/10.1136/adc.2005.071761

Batyrkhanov, A. G., Sadirmekova, Z. B., Sambetbayeva, M. A., Nurgulzhanova, A. N., Ismagulova, Z. S., & Yerimbetova, A. S. (2022). Development of methods and technologies for creating intelligent scientific and educational internet resources. *Bulletin of Electrical Engineering and Informatics*, *11*(5), 2968–2977. https://doi.org/10.11591/eei.v11i5.3075

Becattini, N., Škec, S., Pavković, N., & Cascini, G. (2020). E-LEARNING INFRASTRUCTURE PROTOTYPE for GEOGRAPHICALLY DISTRIBUTED PROJECT-BASED LEARNING. *Proceedings of the Design Society: DESIGN Conference*, *1*, 1667–1676. https://doi.org/10.1017/DSD.2020.282

Bhamre, P., & Jagtap, A. (2021). A case study of use of MKCL supercampus in teaching of basics of electronics engineering to enhance classroom interactions. *Journal of Engineering Education Transformations*, *34*(3), 56–61. https://doi.org/10.16920/JEET/2021/V34I3/152234

Bhamre, P., Vaidya, A., & Nikam, J. (2021). Systematic and rigorous use of feedback to enhance learning in engineering classes. *Journal of Engineering Education Transformations*, *34*(Special Issue), 356–364. https://doi.org/10.16920/jeet/2021/v34i0/157179

Chacon, J., Besada-Portas, E., Carazo-Barbero, G., & Lopez-Orozco, J. A. (2021). Enhancing EJsS with Extension Plugins. *Electronics 2021, Vol. 10, Page 242*, *10*(3), 242. https://doi.org/10.3390/ELECTRONICS10030242

Chandra, V., & Fisher, D. L. (2009). Students' perceptions of a blended web-based learning environment. *Learning Environments Research*, *12*(1), 31–44. https://doi.org/10.1007/s10984-008-9051-6

Chikurtev, D. S., Chikurteva, A. A., & Spasova, N. R. (2021). Information technologies for development of educational resources in robotics. *IOP Conference Series: Materials Science and Engineering*, *1031*(1). https://doi.org/10.1088/1757-899X/1031/1/012122

Conesa, J. I. P. (2022). ADAPTATION TO ONLINE TEACHING OF FIELD PRACTICES IN COASTAL ENGINEERING COURSES. *Human Review. International Humanities Review / Revista Internacional de Humanidades*, *11*(Monografico). https://doi.org/10.37467/revhuman.v11.4161

Daineko, Y. A., Ipalakova, M. T., Aitmagambetov, A. Z., Kulakayeva, A. E., Kozhakhmetova, B. A., & Tsoy, D. D. (2022). Development of a digital educational platform for studying radio engineering courses. *Recent Contributions to Physics*, *82*(3), 71–78. https://doi.org/10.26577/rcph.2022.v82.i3.10

Dong, J., Soeiro, T. B., Koeners, J., & Bauer, P. (2020). Online Laboratory Sessions for the Education of Electrical Machines and Drives. *IEEE International Symposium on Industrial Electronics*, *2020-June*, 430–435. https://doi.org/10.1109/ISIE45063.2020.9152517

Erstad, O. (2006). A new direction?: Digital literacy, student participation and curriculum reform in Norway. *Education and Information Technologies*, *11*(3–4), 415–429. https://doi.org/10.1007/S10639-006-9008-2/FIGURES/2

Farah, J. C., Spaenlehauer, B., Sharma, V., Rodriguez-Triana, M. J., Ingram, S., & Gillet, D. (2022). Impersonating Chatbots in a Code Review Exercise to Teach Software Engineering Best Practices. *IEEE Global Engineering Education Conference, EDUCON*, *2022-March*, 1634–1642. https://doi.org/10.1109/EDUCON52537.2022.9766793

Felder, R. M., Stice, J. E., & Rugarcia, A. (2000). Future of engineering education. Part 6. Making reform happen. *Chemical Engineering Education*, *34*(3), 208–214.

Ferrari, A., Punie, Y., & Bre, B. N. (2013). *DIGCOMP : A Framework for Developing and Understanding Digital Competence in Europe* . https://doi.org/10.2788/52966

Gajbhiye, B. D., Kulkarni, H. A., Tiwari, S. S., & Mathpati, C. S. (2020). Teaching turbulent flow through pipe fittings using computational fluid dynamics approach. *Engineering Reports*, *2*(1), 1–18. https://doi.org/10.1002/eng2.12093

Galustyan, O. V., Solyankin, A. V., Skripkina, A. V., Shchurov, E. A., Semeshkina, T. V., & Ledeneva, A. V. (2020). Application of blended learning for formation of project competence of future engineers. *International Journal of Engineering Pedagogy*, *10*(3), 106–113. https://doi.org/10.3991/IJEP.V10I3.12251

García-Sánchez, S., & Luján-García, C. (2020). Lifelong learning and esp vocabulary: Reflections in telecommunications and ict. *ELOPE: English Language Overseas Perspectives and Enquiries*, *17*(2), 195–218. https://doi.org/10.4312/elope.17.2.195-218

Guo, L., Abdul, N. M. M., Vengalil, M., Wang, K., & Santuzzi, A. (2022). Engaging Renewable Energy Education Using a Web-Based Interactive Microgrid Virtual Laboratory. *IEEE Access*, *10*, 60972–60984. https://doi.org/10.1109/ACCESS.2022.3181200

Haidar, A. M. A., Smith, V., & Elphick, S. (2021). A multipurpose problem-based learning platform for education and research under smart grid umbrella. *International Journal of Electrical Engineering and Education*, *58*(1), 3–32. https://doi.org/10.1177/0020720918816001

Hatlevik, O. E., & Christophersen, K. A. (2013). Digital competence at the beginning of upper secondary school: Identifying factors explaining digital inclusion. *Computers and Education*, *63*, 240–247. https://doi.org/10.1016/j.compedu.2012.11.015

Hernández-Chávez, M., Cortés-Caballero, J. M., Pérez-Martínez, Á. A., Hernández-Quintanar, L. F., Roa-Tort, K., Rivera-Fernández, J. D., & Fabila-Bustos, D. A. (2021). Development of virtual reality automotive lab for training in engineering students. *Sustainability (Switzerland)*, *13*(17), 9776. https://doi.org/10.3390/su13179776

Heulingn, L., & Wild, S. (2021). How Student Characteristics Affect Economy Students' Digital Competences: A latent profile study. *Nordic Journal of Vocational Education and Training*, *11*(1), 44–70. https://doi.org/10.3384/njvet.2242-458x.2111144

Horvat, N., Becattini, N., & Škec, S. (2021). Use of information and communication technology tools in distributed product design student teams. *Proceedings of the Design Society*, *1*, 3329–3338. https://doi.org/10.1017/PDS.2021.594

Illanes, M. K. G., Breda, A., Manríquez, D. D. C., & Martínez, H. A. A. (2022). Analysis of a teaching learning process of the derivative with the use of ICT oriented to engineering students in Chile. *Eurasia Journal of Mathematics, Science and Technology Education*, *18*(7). https://doi.org/10.29333/EJMSTE/12162

Kans, M., Campos, J., & Håkansson, L. (2020). A remote laboratory for Maintenance 4.0 training and education. *IFAC-PapersOnLine*, *53*(3), 101–106. https://doi.org/10.1016/j.ifacol.2020.11.016

Krajčovič, M., Gabajová, G., Matys, M., Furmannová, B., & Dulina, Ľ. (2022). Virtual Reality as an Immersive Teaching Aid to Enhance the Connection between Education and Practice. *Sustainability 2022, Vol. 14, Page 9580*, *14*(15), 9580. https://doi.org/10.3390/SU14159580

Lampón, C., Diaz, J. M., Dormido, S., & Costa-Castelló, R. (2022). An interactive application to analyse the existence of limit cycles using the describing function. *IFAC-PapersOnLine*, *55*(17), 291–295. https://doi.org/10.1016/J.IFACOL.2022.09.294

Mahmood, K., Otto, T., Kuts, V., Terkaj, W., Modoni, G., Urgo, M., Colombo, G., Haidegger, G., Kovacs, P., & Stahre, J. (2021). Advancement in production engineering education through Virtual Learning Factory Toolkit concept. *Proceedings of the Estonian Academy of Sciences*, *70*(4), 374–382. https://doi.org/10.3176/proc.2021.4.02

Martin-Villalba, C., & Urquia, A. (2022). An Approach to Develop Collaborative Virtual Labs in Modelica. *IEEE Access*, *10*, 58938–58949. https://doi.org/10.1109/ACCESS.2022.3179712

Mayer, R. E. (2003). The promise of multimedia learning: using the same instructional design methods across different media. *Learning and Instruction*, *13*(2), 125–139. https://doi.org/10.1016/s0959-4752(02)00016-6

Mikulecký, P. (2012). Smart Environments for Smart Learning. *9th International Scientific Conference on Distance Learning in Applied Informatics*, 213–222. http://conferences.ukf.sk/index.php/divai/divai2012/paper/view/873

Mora, H., Signes-Pont, M. T., Fuster-Guilló, A., & Pertegal-Felices, M. L. (2020). A collaborative working model for enhancing the learning process of science & engineering students. *Computers in Human Behavior*, *103*, 140–150. https://doi.org/10.1016/j.chb.2019.09.008

Moreno, A., & Bartolomé, E. (2021). Study and research paths to improve web-based inquiry learning: Study case of an ICT course in engineering. *Education Sciences*, *11*(12). https://doi.org/10.3390/EDUCSCI11120772

Nadeem, M., Lal, M., Cen, J., & Sharsheer, M. (2022). AR4FSM: Mobile Augmented Reality Application in Engineering Education for Finite-State Machine Understanding. *Education Sciences 2022, Vol. 12, Page 555*, *12*(8), 555. https://doi.org/10.3390/EDUCSCI12080555

Nasralla, M. M. (2022). An Innovative JavaScript-Based Framework for Teaching Backtracking Algorithms Interactively. *Electronics (Switzerland)*, *11*(13), 2004. https://doi.org/10.3390/electronics11132004

Obukhova, L. A., Galustyan, O. V., Baklanov, I. O., Belyaev, R. V., Kolosova, L. A., & Dubovitskaya, T. V. (2020). Formation of Organizational Competence of Future Engineers By Means of Blended Learning. *International Journal of Engineering Pedagogy (IJEP)*, *10*(2), 119–127. https://doi.org/10.3991/IJEP.V10I2.12047

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *The BMJ*, *372*. https://doi.org/10.1136/bmj.n71

Palioura, M., & Dimoulas, C. (2022). Digital Storytelling in Education: A Transmedia Integration Approach for the Non-Developers. *Education Sciences*, *12*(8). https://doi.org/10.3390/educsci12080559

Pando Cerra, P., Fernández Álvarez, H., Busto Parra, B., & Castaño Busón, S. (2023). Boosting computer-aided design pedagogy using interactive self-assessment graphical tools. *Computer Applications in Engineering Education*, *31*(1), 26–46. https://doi.org/10.1002/CAE.22569

Parody, L., Santos, J., Trujillo-Cayado, L. A., & Ceballos, M. (2022). Gamification in Engineering Education: The Use of Classcraft Platform to Improve Motivation and Academic Performance. *Applied Sciences (Switzerland)*, *12*(22). https://doi.org/10.3390/APP122211832

Pertegal-Felices, M. L., Jimeno-Morenilla, A., Sánchez-Romero, J. L., & Mora-Mora, H. (2020). Comparison of the effects of the Kahoot tool on teacher training and computer engineering students for sustainable education. *Sustainability (Switzerland)*, *12*(11). https://doi.org/10.3390/SU12114778

Petchamé, J., Iriondo, I., Villegas, E., Fonseca, D., Yesa, S. R., & Aláez, M. (2021). A qualitative approach to help adjust the design of management subjects in ict engineering undergraduate programs through user experience in a smart classroom context. *Sensors*, *21*(14). https://doi.org/10.3390/s21144762

Pratibha, D., Yalagi, P. S., Dixit, R. K., & Nirgude, M. A. (2021). Effective use of online Teaching-Learning Platform and MOOC for Virtual Learning. *Journal of Physics: Conference Series*, *1854*(1). https://doi.org/10.1088/1742-6596/1854/1/012019

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education*, *93*(3), 223–231. https://doi.org/10.1002/j.2168-9830.2004.tb00809.x

Rahman, M. M., Watanobe, Y., Kiran, R. U., Thang, T. C., & Paik, I. (2021). Impact of Practical Skills on Academic Performance: A Data-Driven Analysis. *IEEE Access*, *9*, 139975–139993. https://doi.org/10.1109/ACCESS.2021.3119145

Romero, E., García, L., & Ceamanos, J. (2021). Moodle and Socrative quizzes as formative aids on theory teaching in a chemical engineering subject. *Education for Chemical Engineers*, *36*, 54–64. https://doi.org/10.1016/j.ece.2021.03.001

Roundy, J. K., Gallagher, M. A., & Byrd, J. L. (2022). An innovative active learning module on snow and climate modeling. *Frontiers in Water*, *4*, 116. https://doi.org/10.3389/frwa.2022.912776

Salah, B., Khan, S., Ramadan, M., & Gjeldum, N. (2020). Integrating the concept of industry 4.0 by teaching methodology in industrial engineering curriculum. *Processes*, *8*(9). https://doi.org/10.3390/PR8091007

Seddighi, M., Allanson, D., Rothwell, G., & Takrouri, K. (2020). Study on the use of a combination of IPython Notebook and an industry-standard package in educating a CFD course. *Computer Applications in Engineering Education*, *28*(4), 952–964. https://doi.org/10.1002/CAE.22273

Sodikin, S. (2017). Traditional Wisdom of Adat Law Baduy Community In Farming System In Kanekes Village, Leuwihdamar Lebak Banten. *Jurnal Cita Hukum*, *5*(1), 89–108. https://doi.org/10.15408/jch.v5i1.5398

Solmaz, S., & Van Gerven, T. (2022). Interactive CFD simulations with virtual reality to support learning in mixing. *Computers and Chemical Engineering*, *156*, 107570. https://doi.org/10.1016/j.compchemeng.2021.107570

Spector, J. M. (2014). Conceptualizing the emerging field of smart learning environments. *Smart Learning Environments*, *1*(1), 1–10. https://doi.org/10.1186/s40561-014-0002-7

Sri Vinodhini, H., Julius Fusic, S., & Bhagyalakshmi, P. (2021). A smart board approach in teaching engineering mathematics course. *Journal of Engineering Education Transformations*, *34*(Special Issue), 271–276. https://doi.org/10.16920/jeet/2021/v34i0/157154

Sumaimi, M. E., & Susilawati. (2021). The role of ICT as a media in learning activities before the COVID-19 pandemic: Undergraduate perspective. *Journal of Physics: Conference Series*, *1882*(1), 012130. https://doi.org/10.1088/1742-6596/1882/1/012130

Unzueta, G., & Eguren, J. A. (2021). Training in higher education in the Covid-19 context: A case study of operation management training in a Business Innovation and Project Management Master. *International Conference on Higher Education Advances*, 253–261. https://doi.org/10.4995/HEAD21.2021.12896

Uskov, V. L., Howlett, R. J., & Jain, L. C. (2015). Smart education and smart e-Learning. In V. L. Uskov, R. J. Howlett, L. C. Jain, & L. Vlacic (Eds.), *Smart Innovation, Systems and Technologies* (Vol. 41). Springer International Publishing. https://doi.org/10.12753/2066-026x-17-186

Valiente, D., Campello-Vicente, H., Velasco-Sánchez, E., Rodríguez-Mas, F., & Campillo-Davo, N. (2021). Assessing the impact of attendance modality on the learning performance of a course on machines and mechanisms theory. *Mathematics*, *9*(5). https://doi.org/10.3390/MATH9050558

van EckNees, N. J., & Waltman, L. (2019). Manual for VOSviewer version 1.6.13. *Uninversiteit Leiden, CWTS Meaningful Metrics*, *January*, 1–53. https://www.vosviewer.com/documentation/Manual_VOSviewer_1.6.13.pdf

van Laar, E., van Deursen, A. J. A. M., van Dijk, J. A. G. M., & de Haan, J. (2017). The relation between 21st-century skills and digital skills: A systematic literature review. *Computers in Human Behavior*, *72*, 577–588. https://doi.org/10.1016/j.chb.2017.03.010

Veide, Z., Veide, Z., & Strozheva, V. (2020). CONTEMPORARY NEEDS OF MEDIA LEARNING MATERIALS FOR FUTURE Z-ENGINEERS. *SOCIETY. INTEGRATION. EDUCATION. Proceedings of the International Scientific Conference*, *4*(0), 681–690. https://doi.org/10.17770/sie2020vol4.4991

Venkatesh, V., Croteau, A. M., & Rabah, J. (2014). Perceptions of effectiveness of instructional uses of technology in higher education in an era of web 2.0. *Proceedings of the Annual Hawaii International Conference on System Sciences*, 110–119. https://doi.org/10.1109/HICSS.2014.22

Vergara, D., Rubio, M. P., Extremera, J., & Lorenzo, M. (2021). Interdisciplinary learning methodology for supporting the teaching of industrial radiology through technical drawing. *Applied Sciences (Switzerland)*, *11*(12). https://doi.org/10.3390/app11125634

Zhu, Z. T., Yu, M. H., & Riezebos, P. (2016). A research framework of smart education. *Smart Learning Environments*, *3*(1), 1–17. https://doi.org/10.1186/s40561-016-0026-2

A case study of gamification and PBL integration as an active learning pathway

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Abstract

This paper presents a case study of gamification and PBL (Problem-Based Learning) integration as toolbox to enhance active learning and to promote problem-solving skills. Gamification can be defined as using game design techniques, game thinking, and game mechanics to improve non-game contexts, with the aim of increasing user interactivity. PBL is one of the learning techniques that use problems as a context for students to get into practice about critical thinking and to obtain knowledge from subject matter problems. An experience was carried out using Quality Tools gamification that was developed for undergraduate students of Mechanical Engineering. These experiences were developed using the teaching role in PBL to set problems, ask questions, and to facilitate students' comprehension. The integrated use of gamification and PBL might turn students into more independent learners, allowing selected learning strategies, and to become able to control the learning process and exploring their creativity. Some results based on student's perspective are showed in this paper. The results shown a comparison between different scenarios for traditional learning methods application and active learning, and the conclusions indicated the benefits of active learning comparing with traditional learning methods. However, it is possible to understand the importance of technology advancement and its significant influence on gamification and PBL integration. It's possible to conclude that the investigated strategy makes problem-based learning process more efficient. The results of this case study have shown that the use of several technologies supported by gamification can increase the chance of improving the learning process.

Keywords: Active Learning; Engineering Education; Problem-Based Learning; Gamification.

1 Introduction

Problem-based learning (PBL) and gamification are two educational strategies that can enhance the effectiveness of teaching and learning in engineering undergraduate courses. PBL promotes student-centred learning by presenting real-world problems that students must solve using critical thinking and problem-solving skills. Gamification, on the other hand, integrates game design elements into the learning process to engage students and increase motivation (Manzano et al. 2021; Markopoulos et al. 2015)

This paper presents a case study of gamification and PBL (Problem Based Learning) integration. It was developed during an undergraduate course of Quality Systems, for Mechanical Engineering, that occurred in 2S2022 and 1S2023. Some results based on student's perspective are showed in this work. The results shown a comparison between different scenarios for traditional learning methods application and active learning.

In this section, the meaning concepts about gamification and PBL are presented.

Engineering education plays a critical role in preparing students for successful careers in a rapidly changing technological landscape. Traditional lecture-based teaching methods have been the norm in engineering education for decades, but they may not be sufficient to prepare students for the challenges of the modern workplace. Problem-based learning (PBL) and gamification are two educational strategies that have gained popularity in recent years as a means of enhancing student learning and engagement (Oliveira et al. 2018; Gamarra et al. 2022)

Problem-Based Learning (PBL) is a student-centered approach to learning that emphasizes critical thinking, problem-solving, and collaboration (Radchuen and Srisomphan, 2021). In PBL, students work in teams to solve real-world problems that are relevant to their course of study. The problems are usually open-ended and require students to apply their knowledge to develop solutions. PBL helps students develop critical thinking skills by presenting them with complex, real-world problems that require them to analyze data, evaluate information, and develop solutions (Gamarra et al. 2022)

One example of PBL in engineering education is the use of design challenges. Students are given a design problem, such as designing a bridge or a machine, and must work in teams to develop a solution. This approach not only teaches students how to apply engineering principles to solve real-world problems, but also helps them develop teamwork and communication skills.

Gamification is the integration of game design elements into the learning process to increase engagement and motivation (Delaney, 2021) This approach can help students stay motivated and interested in their coursework by making the learning experience more enjoyable and interactive. Gamification can take many forms, such as using leaderboards, badges, and rewards to incentivize student learning.

One example of gamification in engineering education is the use of simulations. Simulations provide students with a virtual environment in which they can experiment with different engineering concepts and see the results of their actions. By making the learning experience more interactive and engaging, simulations can help students develop a deeper understanding of engineering concepts.

The use of PBL and gamification in engineering education has several benefits (Everaldo Jr. at al. 2019) First, these strategies promote active learning by requiring students to engage with the material and apply their knowledge to solve problems. Second, they help students develop critical thinking and problem-solving skills that are essential for success in the modern workplace. Third, they increase student motivation and engagement by making the learning experience more enjoyable and interactive.

Implementing PBL and gamification in engineering courses requires careful planning and execution. Instructors must select appropriate problems and game design elements that are relevant to the course content and align with the learning objectives. Instructors must also provide students with the necessary support and resources to ensure that they can successfully complete the tasks.

One example of implementing PBL and gamification in an engineering course is the use of a semester-long project (Fernandez-Antolin et al. 2021). Students work in teams to develop a solution to a real-world problem, such as designing a sustainable building. Throughout the semester, students receive feedback and support from the instructor and peers. In addition, the project is gamified by using badges and rewards to incentivize student participation and achievement.

Finally, PBL and gamification are two educational strategies that can enhance the effectiveness of teaching and learning in engineering undergraduate courses. These strategies promote active learning, critical thinking, problem-solving, and student motivation.

2 Gamification and PBL Practical Applications

There are several examples of practical applications of PBL and gamification in engineering education. In this section, the meaning types are cited (Lluch-Molins, 2022

Engineering design challenges: Students are given real-world design challenges that require them to identify problems, develop solutions, and create prototypes. By using PBL, students can work collaboratively, apply critical thinking skills, and learn from their mistakes. Gamification elements, such as leader boards and rewards, can be incorporated to increase motivation and engagement.

Simulations and virtual labs: Simulations and virtual labs are a great way to provide students with hands-on experiences in a safe and controlled environment. By using gamification elements, such as badges and achievements, students can be motivated to explore different scenarios and experiment with different solutions.

Mobile learning apps: Mobile learning apps that use gamification elements, such as game-based quizzes and challenges, can be an effective way to engage students in learning. By incorporating PBL principles, such as real-world problem-solving and collaborative learning, students can gain practical knowledge and skills that they can apply in their future careers.

Serious games: Serious games are games that are designed for a specific purpose, such as education or training. By using gamification elements, such as points, levels, and badges, serious games can be an effective way to engage students in learning. These games can also provide students with practical experiences that they can apply in real-world situations, working as teams and enable for extensive discussions and exchange of experiences with international experts.

Case studies and problem-based learning: Case studies and problem-based learning are common methods used in engineering education. By using gamification elements, such as competition and rewards, students can be motivated to work harder and learn more effectively. These methods can also help students develop critical thinking and problem-solving skills that are essential for success in engineering.

3 Methodology

In this section, the methodologies PBL and Gamification integration are deployed.

The first step was to define the discipline where the case study would be developed. It was defined that undergraduate course of Quality Systems, for Mechanical Engineering students of 9th semester would be selected.

The second step was to identify the topic of the discipline that will be carried out. At this point, the quality research group of industrial engineering department chose the topic “the seven basic quality tools” would be part of the case study.

According to (Abdel-Hamid and Abdelhaleem, 2019), the seven basic quality tools are: Control Charts, Pareto Diagram, Ishikawa Diagram, Histogram, Stratification, Checklist and Correlation Diagram (Scatter Plot).

For this case study, was developed a game called “The Tower of Babel” that aims to support the teaching of Correlation Diagram. “The Tower of Babel” Game was based on the history of its construction (Pozzer, 2020). Babylon was the main religious and cultural pole in Southern Mesopotamia, and the capital of the biggest empire of Eastern world before Persian, between 7th and 6th centuries BCE. It was built by the Euphrates River, around 55 miles (90 km) from the South of current Baghdad. Reports on the Tower of Babel building were present in some verses from the Book of Genesis (Gen. 11, 1-9).

The Tower of Babel would probably have two major functions of two different natures: scientific and religious. Scribes used to make daily astronomic observations, reporting the results on clay tablets. The Tower's great staircase had also a religious function, once according to the imaginary of that time, it would make easier for gods go down from Heaven to relieve men's pains and sufferings.

According to the Book of Genesis, Tower of Babel is a biblical myth that narrates the construction of a tower that would reach the heavens. God would have caused confusion in humanity by establishing different languages, which prevented the tower from being built. This myth is found in Genesis 11:1-9.

In the game developed by students of Industrial Engineering in an extracurricular project conducted in 2S2021, the main reason for the tower interruption built was the raw material transportation. It was a free and humorous adaptation of the myth, aiming to facilitate its adaptation as a game based on PBL.

A lot of difficulties and constraints in the road to the Tower of Babel site, were the causes of its definitive interruption.

The next section shows the game procedure when the authors intended to integrate and apply gamification and PBL concepts.

4 Game Procedure and Obtained Results

Figure 1 shows the first screen of "Tower of Babel" game.

Figure 1. First screen of the game

Clicking in "INICIAR" the following screen (Figure 2) will show the problem to be solved: "Why the construction of the tower has been constantly delayed? It is because delivery of materials is always delayed. The road conditions are precarious and delay the delivery of materials needed to build the tower, increasing transportation time. A transportation time chart shows hours per day for each month, during three consecutive periods".

Mês/Dia	1	2	3	4	5	8	9	10
Setembro	1,98	2,34	1,79	2,63	2,35	1,68	1,95	1,94
Outubro	1,54	2,68	2,21	2,28	1,70	2,76	1,62	2,38
Novembro	3,36	3,59	4,37	3,74	4,06	3,64	4,08	3,39

Mês/Dia	11	12	13	14	15	18	19	20
Setembro	1,35	2,33	2,39	1,69	2,85	2,29	1,57	2,24
Outubro	1,44	2,60	1,19	2,25	2,92	2,81	3,30	2,82
Novembro	3,82	4,53	4,87	4,23	3,74	3,85	4,40	4,07

Mês/Dia	21	22	23	24	25	28	29	30
Setembro	1,60	2,28	2,42	2,43	2,25	2,82	1,95	2,19
Outubro	2,92	3,16	3,32	3,68	2,96	3,60	2,73	3,35
Novembro	3,54	4,59	3,91	4,43	3,40	3,69	3,49	4,17

Figure 2. Problem Definition and table of transportation times

The students ("problem solvers") can read several reports about people that uses the road daily. Figure (3) shows the available reports (from Irineu, Sherazade, Osman, Salomão e Isaac). They are workers of the tower building, and each of them has their own thinking about delay reasons (causes) that delayed transportation (effect).

At this point of the game, students analyze reports and charts considering weather and road conditions, like: rain intensity, sunlight, number of horses for transportation, road holes, temperature variations and number of accidents on the road. Using the reports data and charts, students can evaluate the influence of weather and road conditions (potential causes) and the transportation time (effect). Analyzing inputs and outputs, students can solve the problem, using correlation diagrams. So, the main objective of this problem will be reached. Even without previously knowing about correlation diagram (Scatter Plot), the students can solve the problem, studying and analyzing cause and effect relations.

Figure 3. Workers Report (Example of Osman)

Figure (4) presents the screen for hypotheses that may affect transport time: rain conditions, climate conditions, road holes frequency, number of horses on the road, sunlight periods, temperature variation and number of accidents per day.

Mês/Dia	1	2	3	4	5	6	7	8	9	10
Setembro	37	28	20	21	11	44	12	10	26	50
Outubro	17	48	24	41	18	45	42	39	17	44
Novembro	86	75	74	81	97	68	81	85	96	74

Mês/Dia	11	12	13	14	15	16	17	18	19	20
Setembro	28	34	34	37	43	22	16	28	15	22
Outubro	30	39	43	55	30	29	22	45	30	52
Novembro	92	83	80	69	77	94	85	83	87	84

Mês/Dia	21	22	23	24	25	26	27	28	29	30
Setembro	12	15	46	34	20	16	13	48	38	26
Outubro	57	34	34	27	24	63	28	60	35	63
Novembro	79	87	81	73	82	84	84	84	73	78

Figure 4. Hypotheses that may affect transport time and "Number of Horses" example

Authors applied this game for two different students' groups, during two different semesters (2S2022 and 21S2023). After the game applications, students answered a questionnaire with open questions, to evaluate the perceived differences in learning, considering the quality tool "Correlation Diagram" (using gamification and PBL) with the other quality tools, worked in the traditional way of teaching. The evaluation criteria used in the questionnaire was based on Reis et al. (2020).

Students from the Fundamentals of Administration course participated in the research. In two consecutive semesters, at the end of each semester, the students answered a questionnaire that addressed aspects such as motivation, engagement, collaboration, and proactivity. All participating students are enrolled in the Engineering courses at EE Mackenzie and are currently in the basic cycle of their respective programs.

The class for 2nd semester 2022 consisted of 37 students, and the class for 1st semester 2023 consisted of 32 students, both characterized by a predominance of male students. The questionnaire participation rate was 82% (2nd semester 2022) and 85% (1st semester 2023), respectively.

The comparison of results was conducted by evaluating the perceived learning characteristics of the students regarding their experience with the Correlation Diagram (which used PBL as a learning tool) and the other basic quality tools (presented in the traditional manner).

The main results are showed in Table 1.

Table 1. Obtained Results – Criteria Evaluation

Criteria Evaluation	**Correlation Diagram**	**Other Quality Tools**
Learning Method	*Use of gamification and PBL*	*Use of traditional way of learning*
Engagement		
Motivation		
Learning Speed		
Concept Learning		
Ability to apply		
Standardization		
Structured method		

The obtained results shows that the use of PBL and gamification can be used to support the learning of quality tools. Engagement, motivation, concept learning and ability to apply are the criteria evaluation where the use of PBL and gamification were considered better than traditional learning.

However, when PBL and gamification are compared with traditional teaching and learning methods, the insertion of active learning tools must be guided by a planning stage, where the results to be obtained are previously outlined and the introduction of tools takes place gradually and considering the profile of students and their motivations.

5 References

Abdel-Hamid, M. and Abdelhaleem, H.M. (2019) Improving the Construction Industry Quality Using the Seven Basic Quality Control Tools. Journal of Minerals and Materials Characterization and Engineering, 7, 412-420. https://doi.org/10.4236/jmmce.2019.76028Delaney, K., Nagle, G. and Chen, M. (2021), Gamification of Icebreaking Activities for Mechanical Engineering Students Embarking on a Problem Based Learning Module. INTED 2021, 8-9 March 2021. doi: 10.21125/inted.2021.2221

Everaldo Jr et al. 2019. Systematic literature review of Gamification and Game-based Learning in the context of Problem and Project Based Learning approaches. https://www.researchgate.net/publication/334046201

Fernandez-Antolin, Maria Mar, Del Río, Manuel, Gonzalez-Lezcano, Roberto Alonso. The use of gamification in higher technical education: perception of university students on innovative teaching materials. International Journal of Technology and Design Education (2021) 31:1019–1038 https://doi.org/10.1007/s10798-020-09583-0

Kladchuen, R. and Srisomphan, J. The Synthesis of a Model of Problem-Based Learning with the Gamification Concept to Enhance the Problem- Solving Skills for High Vocational Certificate. iJET – Vol. 16, No. 14, 2021. https://doi.org/10.3991/ijet.v16i14.20439

Lluch-Molins, L., Balbontin-Escorza, F.Y., & Sullivan-Campillay, N. (2022). Enhancing cooperative learning and student motivation with gamification strategies: A case study in industrial engineering. Journal of Technology and Science Education, 12(3), 611-627. https://doi.org/10.3926/jotse.1693

M. Gamarra, A. Dominguez, J. Velazquez, and H. Páez, A gamification strategy in engineering education – a case study on motivation and engagement, Comput Appl Eng Educ. 2022;30:472–482. https://doi.org/10.1002/cae.22466

M. Trinidad et al.: Bibliometric Analysis of Gamification Research. IEEE ACCESS. VOLUME 9, 2021. DOI 10.1109/ACCESS.2021.3063986

Manzano-León, A.; Camacho-Lazarraga, P.; Guerrero, M.A.; Guerrero-Puerta, L.; Aguilar-Parra, J.M.; Trigueros, R.; Alias, A. Between Level Up and Game Over: A Systematic Literature Review of Gamification in Education. Sustainability 2021, 13, 2247. https://doi.org/10.3390/su13042247

Markopoulos, Angelos P; Anastasios, Frangkou; Kasidiaris, Petros D.; Davim, Paulo; Gamification in engineering education and professional training. International Journal of Mechanical Engineering Education 2015, Vol. 43(2) 118–131 DOI: 10.1177/0306419015591324

Oliveira, Milena S., Leal, Fabiana, Maciel, Tanita C.P. 2018, APLICAÇÃO DA GAMIFICAÇÃO NO ENSINO: UM ESTUDO SOBRE ALGUMAS LACUNAS APRESENTADAS NA LITERATURA. Anais do XXXVIII Encontro Nacional de Engenharia de Produção. ENEGEP.

Pozzer, K.M.P. (2020) The Memory of The Tower of Babel: between Mith, History and Art. RES Antiquitatis 2 (2020): 16-34

Reis, A. C. B., Silva Júnior, E., Gewehr, B. B., & Torres, M. H. (2020). Prospects for using gamification in Industry 4.0. Production, 30, e20190094. https://doi.org/10.1590/0103-6513.20190094.

Applying Mirror Discipline Concept and Project Based Learning to enhance Active Learning

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Abstract

This paper presents an experience of applying Mirror Discipline Concept and Project Based Learning (PBL) method to enhance Active Learning results. Mirror discipline concept refers to a discipline that is offered in two or more institutions of higher education, usually in different countries, and that have similar or identical content and workload. This approach allows students to access a wider range of higher education disciplines and institutions. In this work, an experience involving undergraduate courses of Mechanical Engineering at Mackenzie Presbyterian University in Brazil and a US University was developed. Students of Mechanical Design from both universities were challenged to develop prototypes to meet predefined demands and the same design objectives. Each group of students was guided by a professor from their home university. This experience was repeated for 3 consecutive semesters. The results of the experience show considerable gains in learning, collaborating, improving student's learning experience, for the development of soft and hard skills.

Keywords: Engineering Education; Project Based Learning, Global Engineer Knowledge, Mirror Discipline.

1. Introduction

Engineering education plays a critical role in preparing students for successful careers in a rapidly changing technological landscape. Traditional lecture-based teaching methods have been the norm in engineering education for decades, but they may not be sufficient to prepare students for the challenges of the modern workplace.

Transformative learning theory suggests that individuals can change their perspectives, assumptions, and ways of thinking through critical reflection and questioning of their beliefs. This theory has significant implications for education, particularly in engineering, where the ability to adapt and evolve is critical to success. This article explores the interaction between transformative learning, project based learning and mirror disciplines in engineering education, showing an experience of applying Mirror Discipline Concept and Project Based Learning (PBL) method to enhance Active Learning results.

According to OECD, 2019 to meet the challenges of the 21st century, students need to be empowered and feel that they can aspire to help shape a world where well-being and sustainability – for themselves, for others, and for the planet. These transformative competencies can be used across a wide range of contexts and situations and they are uniquely human. The transformative competencies can be taught and learned in schools by incorporating them into existing curricula and pedagogy. Students need to acquire three transformative competencies to help shape the future we want: creating new value, reconciling tensions and dilemmas, and taking responsibility..

Students who are best prepared for the future are change agents. They can have a positive impact on their surroundings, influence the future, understand others' intentions, actions and feelings, and anticipate the short and long-term consequences of what they do. (OECD, 2019)

WGU, 2020 in their text, explain that transformative learning is a theory and the founder was Jack Mezirow. They put in the article the following definition: of transformative learning: "an orientation which holds that the way learners interpret and reinterpret their sense experience is central to making meaning and hence learning." They explain that "transformative learning is the idea that learners who are getting new information are also evaluating their past ideas and understanding, and are shifting their very worldview as they obtain new information and through critical reflection". The learners find meaning in what they understand and this takes to a new perspective an insights, levering questions about how to use this knowledge. The text also comment that "Many learners and experts agree that this kind of learning leads to true freedom of thought and understanding.

WGU, 2020 also explain the seven phases of the Mezirow theory, they are: Disorienting dilemma, Self-examination, Critical assessment of assumptions, Planning a course of action, Acquisition of knowledge or skills to carry out new plan, Exploring and trying new roles., Building self-efficacy in new roles and relationships.

According to Garcia (2019) apud ITM (2018), "a mirror class is an academic resource that uses a digital platform shared between professors and students from two or more universities, to participate in the synchronous and asynchronous development of a complete course or a session of a course".

Globalization and educational challenges are an opportunity to innovate in the educational field, especially to create spaces that promote the exchange of knowledge and collaboration in the teaching process.

The mirror class strategy implies that two or more professors who teach equivalent courses in different national or foreign universities get in touch to share their subject programs, activities, resources and their knowledge, defining some common contents that can be worked on collaboratively. This strategy can incorporate practical activities managed at a distance and coordinated by professors and can even bring together students from different universities involved in the same work team. This contributes to active, student-centered learning and to the implementation of new ways of teaching and learning, promoting the internationalization of teaching and the globalization of learning.

Project Based Learning (PBL) is a teaching method in which students learn by actively engaging in real-world and personally meaningful projects. (Bucks, 2023)

Figure 1 show the essential project design elements for development of a PBL: (Buck, 2023)

Figure 1 – Gold standard PBL (bucks 2023)

Challenging problem or question - The project is framed by a meaningful problem to be solved or a question to answer, at the appropriate level of challenge.

Sustained Inquiry - Students engage in a rigorous, extended process of posing questions, finding resources, and applying information.

Authenticity - The project involves real-world context, tasks and tools, quality standards, or impact, or the project speaks to personal concerns, interests, and issues in the students' lives.

Student Voice and Choice - Students make some decisions about the project, including how they work and what they create, and express their own ideas in their own voice

Reflection – Students and teachers reflect on the learning, the effectiveness of their inquiry and project activities, the quality of student work, and obstacles that arise and strategies for overcoming them

Critique and Revision – Students give, receive, and apply feedback to improve their process and products.

Public Product - Students make their project work public by sharing it with and explaining or presenting it to people beyond the classroom

The interaction between transformative learning and mirror disciplines in engineering education is particularly important because engineering is a discipline that requires the ability to adapt and evolve. Students must be able to think critically and challenge their assumptions, particularly when faced with new and complex problems.

Through mirror disciplines, students can develop critical reflection skills and the ability to question their assumptions, which can ultimately lead to transformative learning experiences.

The challenge that presents itself in engineering education, in addition to the ability to adapt, is to understand the existence of a common technical knowledge and its application in the real world. This common technical knowledge is not exclusive to an institution or country of origin, an engineer must be able to work professionally anywhere in the world. Must be able to technically discuss with another engineer regardless of language.

One way of bringing engineering students from different educational institutions that are located in different places around the world together solving problems is with the use of the mirror discipline that allows exchanging experiences in the solution of real problems this two methodology together have the opportunity to mix the learning experiences with students of different cultures, this combination is a powerful tool in Engineering Education.

2. Methodology

The intention in this study is to show how the union of these two methodologies, PBL and mirror classes, becomes a way to bring students closer and closer to a real experience of professional performance.

The process began with the application of the PBL methodology in a discipline of the course, in this case, the discipline is design and development of prototypes in the seventh semester of mechanical engineering. In this discipline applies machine building concepts with the aim of solving a real problem, from concept to manufacture.

The PBL process was applied to the discipline in the following steps:

- Conceptual lecture on elements that make up the design process
- Division of students into groups (self-administered)
- Exposure of the challenge highlighting the constraints of environment, material, time and communication

- Consulting classes to evaluate the progress of the project
- Intermediate assessments to guide project development
- Final presentation of how the project works
- Sharing the result and development through video.

To this process, due to the perception of the need for internationalization, an adaptation of the mirror class is added, as the activities are not carried out simultaneously.

The mirror class process takes place with the following steps:

- Elaboration of the project briefing in the language of the partner institution
- Discussion of the project with the partner professor in order to adjust the characteristics of the discipline, culture and time
- Determining challenge application and sharing dates
- Availability of contact details for groups of Brazilian students (these start earlier)

All proposed projects were done in groups, with an average of 4 students per group. The evaluation was divided into three stages, drawings, execution of the challenge and video, always evaluated using evaluation rubrics. this evaluation process focuses on engineering skills, however, even though they are not part of the grade, transforming learning skills are charged.

3. Application

The process began with the perception of the quality of the course when comparing the curriculum with institutions outside Brazil, at this moment it is highlighted that there is a set of basic knowledge in the engineering course that permeates all institutions regardless of the country of origin. This set of basic knowledge translates into an "*engineering language*" that, despite the different languages around the world, is of common understanding for students, so when attending similar contents, regardless of the name of the discipline, they can exchange information, experiences and practices because they are experiencing the same engineering concepts.

Once the "*engineering* language" becomes clear, an international partner is sought, preferably with a language other than Portuguese, to evaluate the condition of ease interaction between students taking courses with similar contents. Because it is the mechanical engineering course, a mechanical design discipline was chosen to make ease to find a pair in another institution. Of the various international partners, one was chosen by the internationalization representative for having a person of his knowledge in the staff of the institution with availability and enthusiasm to contact the department and professors. After some exchanges of messages, the professor of the discipline Design became interested in doing an exercise with the discipline design and development of prototypes.

The objectives of the discipline design and development of prototypes taught in the seventh semester of the mechanical engineering course are: understand the stages of product design, recognize the importance of creativity in product design, identify the role of project management, analyze the role of computational tools in the development of a prototype, design and build a prototype. The design discipline is offered in two consecutive semesters, seventh semester design I and eighth semester design II also in the mechanical engineering course. Design I address design problems characteristic of mechanical engineering, considering cost, design optimization, codes and standards, and ethics. Design II follows with the making of the prototype planned in design I.

Work between the disciplines began in 2020 with the aim of showing that the "*engineering language*" had no bondaries. After some understandings, the briefing of the challenge proposed for the discipline design and development of prototypes was translated into English and used by the American University. At this time, due to the covid-19 pandemic, both classes were taking place live online. In Brazil was developed only the sketches and drawings in CAD and in the American University, used as one of the lectures of the course of design I. The presentations of the work of the American University were recorded, and here in Brazil was prepared a video, explaining the characteristics of the project, spoken in English by the students, there was then the first exchange of experiences.

A challenge imposed between the disciplines is the issue of the calendar, here in Brazil the content (design process, design and construction) are developed in one semester, and the design process occurs at the beginning of the semester, in the American University, the content of the design process takes place at the end of the semester so, the common part of the proposed challenge occurs at different times, at the beginning of the semester in Brazil and at the end of the semester in the USA, this justifies the sharing of experiences via videos.

In Figure 2, an example of the sketches of the first challenge proposed together in the second half of 2020, where the goal was a mechanism to climb stairs.

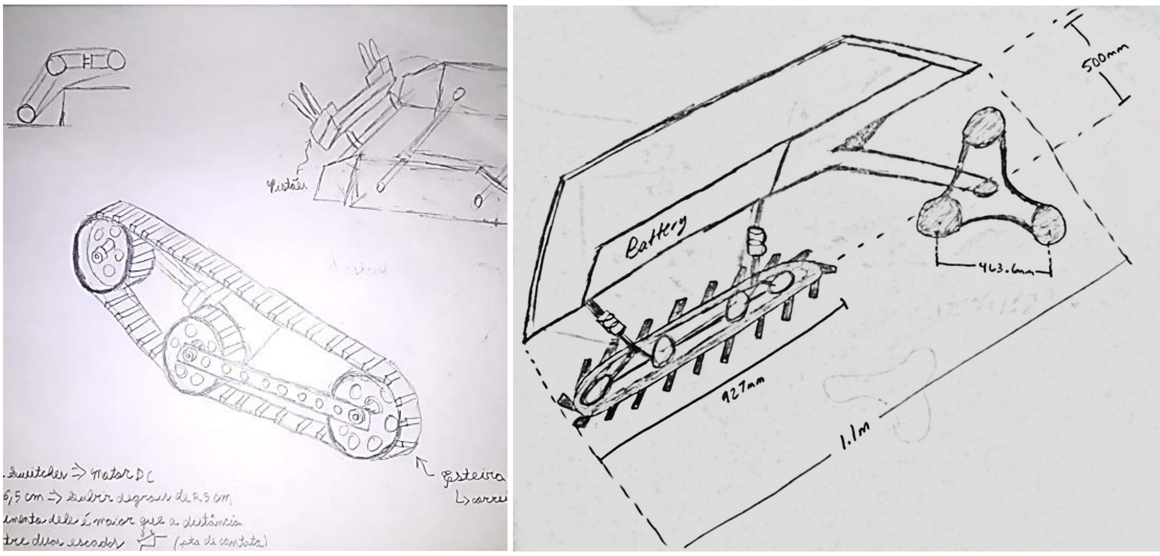

Figure 2 – left, sketch from Brazil, Right sketch from American.

In the following years, until the present date, the same scheme was used, where the challenges of the discipline of prototype design were translated and used by both institutions always with the exchange of experiences made from the videos. It is important to note that the use of the English language both in the briefings and in the videos of the projects were well accepted by the Brazilian students without any unfavorable comments and the American students were invited to integrate the groups of Brazilian students in the process of elaborating the solution to the challenges. Table 1 lists the challenges made by the two institutions together.

Table 1 – List of proposed challenges

Date	Challenges
2020/2	Climb Ladder
2021/1	Move piece with special shape
2021/2	Maxion Wheels Workstation
2022/1	Simulation of artery clearance
2022/2	Repair of broken pipe
2023/1	Remove encrustation in curved pipe

In addition to the gains in engineering processes, many discussions took place about the results obtained with the PBL methodology and transformative learning. The points raised below were positively impacted by the mirror class and the reports presented are based on a qualitative analysis of the students' actions in the course of the discipline.

Some points can be highlighted from this work together, looking Mirror classes, Transformative learning and PBL:

- The understanding that there really is an "*engineering language*" and that despite the geographical distance and the difference in language, the results presented had a similarity both in the process of understanding the challenge and in the engineering tools used in the solution;
- The English language was not a barrier to understand the challenge as well as presenting them to American peers, showing the importance of knowledge of another language in professional development.
- Students understanding the quality of the work developed within their educational institution: students are able to see that the range of disciplines offered are world-class and allow the development of a complete professional. This and the next item are related with the first phase of transformative learning where they find that what they thought or believed in the past may not be accurate.
- Students understanding the quality of the contents developed in the disciplines of the course: students perceive that the contents of the disciplines are in line with international institutions and with the needs of the national and international market.
- Encourage exchanges between institutions: shows the existence of partner institutions for exchange and shows that the contents taught give you the ability to study disciplines outside the institution
- Show the other teachers the quality of the contents developed and the possibility of interdisciplinary exchange: professors feel encouraged to look for new partners to share experiences
- Allow the student to get involved in situations for the application of softskills: the development of group tasks is mainly encouraged using self-administration where the group itself creates the dynamics of interaction involving all the six pillars of institutional transformative learning program, being them, ethics, leadership and entrepreneurial skills, sustainability and collective well-being, critical reflection and cultural and global communication and competence. This is in phase with two last OECD transformative competencies, reconciling tensions and taking responsibility.
- Allow the student to get involved in ethical situations: develops the evaluation of group work. The plan allows changes between groups in case of disagreement. This softskills has stood out in recent periods with the increase in requests for withdrawal from non-active members of the working group.
- Allow the students to start to have better perception of their actions in an engineer project and the impact of their engineer choices in the environment and society. And they start asking questions about how this exercise will reflect in their future professional relationships, this connect to the first OECD transformative competencies, creating new values and with the second phase of the Mezirow Theory when students will do a self-examination of their beliefs and understanding

Looking at these points, it is possible to perceive the alignment with the challenges of the 21st century of the OECD. Despite observing some reports related to transformative learning, a survey observing the seven phases can bring more clarity in relation to this aspect of the actions undertaken

4. References

Bucks Institute for education (2023) What is PBL?. Available in < https://www.pblworks.org/what-is-pbl> access on 24/04/2023

Novoa, Ruth; Vergana, Christian; Roa Efrain, (2022) Clase espejo como estrategia de enseñanza -aprendizaje colaborativo en asignaturas deespecialidad en Ingeniería, utilizando tecnologías de Información y comunicación, Encuentro Internacional de Educacion en Ingenieria ACOFI. Doi: https://doi.org/10.26507/paper.2703

Garcia, Hilda Buttrago (2019). The mirror class as a multi-campus teaching and learning, available in < https://www.researchgate.net/publication/336445674_The_Mirror_Class_As_a_Multi-Campus_Teaching_and_Learning_Experience> access on 24/04/2023

OECD (2019), Future of educationand skills 2030. Available in https://www.oecd.org/education/2030-project/teaching-and-learning/learning/transformative-competencies/Transformative_Competencies_for_2030_concept_note.pdf access on 24/04/2023

WGU, Wester Governors University (2021). What is the transformative learning theory, available in < https://www.wgu.edu/blog/what-transformative-learning-theory2007.html#close> access on 24/04/2023

Enhancing Learning Effectiveness with Online Educational Platforms: Insights from the Use of Prairie Learn in a Data Science Classroom

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Abstract

Online educational platforms have gained increasing popularity in recent years as a means of facilitating student learning and engagement. One such platform is Prairie Learn, which enables educators to parametrize automatically graded questions for students. In this study, we examined the use of Prairie Learn in an engineering course and its impact on student engagement and performance. Our analysis of student data revealed a significant positive correlation between engagement with Prairie Learn and performance in the course. However, we also found that simply using randomized questions was not sufficient to prevent potential sharing of solutions. Another key finding was that students tended to leave interactions with the platform to the last days, which hindered the effectiveness of Prairie Learn as a learning tool. To address these issues, we recommend integrating Prairie Learn into the regular course curriculum and setting short deadlines for completing smaller online activities. Overall, our data highlights the potential benefits of online educational platforms like Prairie Learn as support course material.

Keywords: Prairie Learn, Learning Management Systems, Course Design.

1 Introduction

Learning Management Systems (LMSs) like Moodle and Blackboard can provide support both for distance and in-person learning. Their relevance is growing, and while new tools are appearing, the use of traditional ones is growing (Mustafa and Ali, 2023). LMSs are especially relevant because they allow increasing a course's reach and scale by automating time-consuming tasks such as dealing with enrolments, keeping track of student's engagement, and providing students with timely and high-quality feedback on activities.

An innovative LMS called Prairie Learn was developed with a focus on this last task (West et al., 2015). Prairie Learn allows building assignments with questions whose parameters are randomly chosen for each student, potentially providing each learner with their own personalized questions (Moosvi et al., 2021). Consequently, Prairie Learn favours students to reflect on the processes leading to an answer, rather than focusing on finding a specific answer.

As it is the case of many novel tools, the best practices in using Prairie Learn are still being discussed, including reflections on how to avoid cheating (Chen et al., 2018) and how to use the PL platform within a course (Nip, 2018). We contribute to this discussion by bringing engagement and performance data from students in an undergraduate-level Data Science course that used Prairie Learn. These data reveal that, although engagement with PL activities is positively correlated to performance in a final, in-person, exam, there are many external factors, such as credit value and deadlines, that can impact its effectiveness for each individual student.

As it is the case of most learning experiences, there are several concerns on how Prairie Learn fits into a course design. In this work, we use students' interaction data to elucidate the following scientific (Wintersberger & Saunders, 2020) questions:

1. **How long did students take to perform the assessments?** This question is important because assessments that take too long can be hard to complete within regular working weeks, while assessments that take too short can be considered too easy both by students and teachers.
2. **Did students engage in doing the exercises?** Although the Prairie Learn activities were designed as a formative learning activity, there is a possibility that some students might have rushed through it. This behaviour would harm the first purpose of using the platform.
3. **What was the impact of the platform in student's performance?** Even if Prairie Learn fits within a course design and promotes student engagement with the material, its purpose is to improve learning in an observable measure.

This article is divided as follows. Section 2 discusses the course design. Section 3 discusses the data analysis and shows the correlation between engagement with PL and the performance in the final exam. Finally, Section 4 brings forward conclusive remarks and highlight main insights from this work.

2 Course design

The Data Science course we analyse was offered to second-semester students of a Computer Science degree in a private, non-profit school found in São Paulo, Brazil. In total, there were 29 students. Two of them dropped out of the course and were removed from our study, that is, our statistics used a total of 27 students.

The course was divided into two parts, each culminating in an in-person exam. The Prairie Learn platform was used in the second part, thus it could only impact students' performance in the second exam.

Prairie Learn exercises were divided into 14 assessments, each related to the contents of a different class. Regardless of their content, the deadline for all assessments was the day before the final exam. The average assessment grade counted as 10% of the course grade, with the restriction that those who had less than 50% of the grade in the Prairie Learn exercises would automatically fail the course.

The data analysis procedures were conducted taking these design choices into account, as shown in the next section.

3 Data analysis

3.1 Engagement with PL activities

We examined students' interaction with the platform. Specifically, we looked at three factors: the total time spent in the platform, the time taken to complete each assessment, and the number of assessments performed by each student.

Figure 1 shows the histogram of total hours spent on PL assessments per student. Throughout the course, students used from 2.4h to 17h to complete the 14 assessments. This data series has an average of 8.5h and a median of 7.9h, which means it takes an average student between 30 to 40 minutes to complete each assessment. This indicates that the students were not overwhelmed by the assessments.

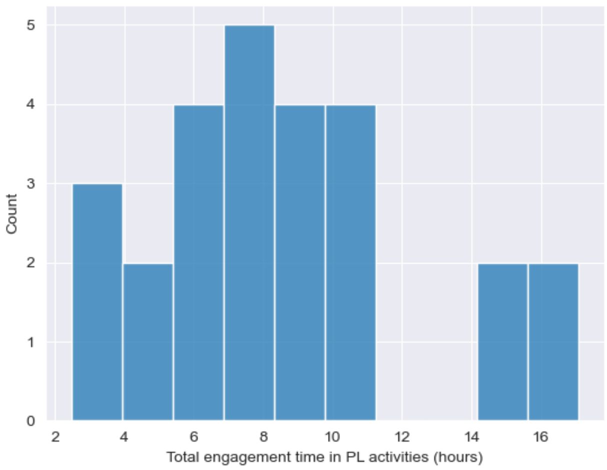

Figure 1. Histogram of total hours spent on PL assessments per student.

In a more refined analysis, we analysed the time taken for each student to complete each assignment. For such, we considered each pair student-assignment as a different data point. Figure 2 shows a histogram of these data.

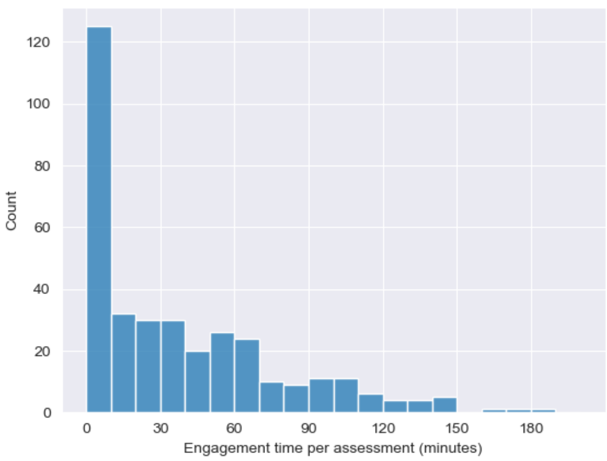

Figure 2. Histogram of minutes spent by students on each PL assessment.

In this histogram, it is possible to notice a problematic behaviour. The students completed 35% of the assessments in less than 10 minutes. Since the assessments were composed of multiple exercises where there is usually a contextualization of the problem before the question, it is highly unlikely that students solved all the exercises so quickly, that is, this could be evidence of cheating. Consequently, these data suggest that, although Prairie Learn can generate exercises with different parameters for each student, this alone is not enough to prevent students from sharing the answers to the exercises among themselves.

We also observed that most assignments started were only accessed in the last week of class, as show in Figure 3. This indicates that students were trying to complete, in one week, tasks that were planned to be distributed over four months. Such a behaviour probably arises from poor time management skills, and lead students to put themselves in situations in which sharing solutions seem the only viable choice.

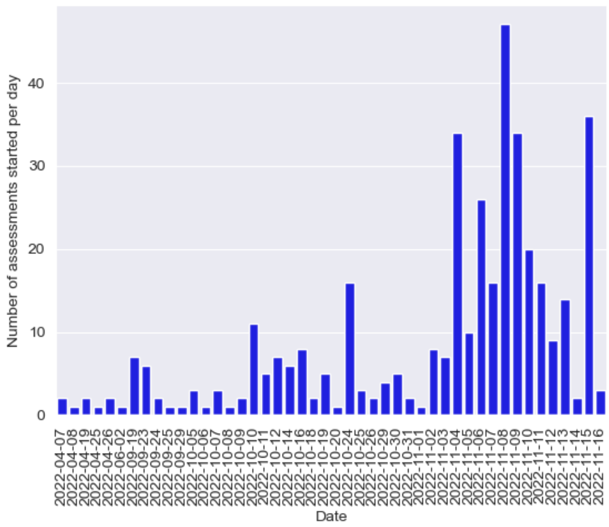

Figure 3. Histogram of assessments started each day, indicating that most assessments were started in the last week of class.

After that, we decided to consider that a student can only be considered to have engaged with an activity if they spent more than a pre-fixed amount of time doing the assessment. We chose this lower bound as 10min, as it seems to be a reasonable threshold to divide the histogram in Figure 2. Then, we associate each student with the fraction of activities they engaged, as shown in Figure 4.

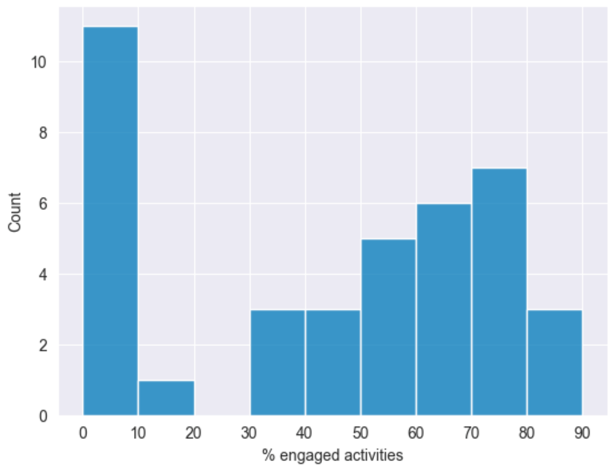

Figure 4. Number of students according to the percentage of assessments they engaged with.

Figure 4 show that a high number of students – almost 1/3 of the class - engaged very little with the assessments. However, among students who did engage, the majority engaged with more than 50% of the assessments, which was the minimum required to avoid failing the course. Thus, we can see that there are mainly two groups of students: those who were not engaged, and those who were very engaged with the exercises.

3.2 Time spent and grade per assessment

In this section, we investigate whether the time students spent on each assessment was related to their performance on that assessment. Figure 5 shows a scatter plot of the students' engagement time in each assessment and their respective grade in the assessment. For a better visualization, we present the time in logarithmic scale, that is, a linear step in the horizontal axis means doubling the engagement time.

Figure 5. Scatter plot between the $\log_2$ of engagement time in each assessment and the respective grade.

Figure 5 shows two groups: a group that gets the maximum grade in assessments regardless of the time used and another whose grades vary according to time. We used data from the second group to fit a linear regression, whose results are shown in Figure 6.

Figure 6. Linear regression between the $\log_2$ of engagement time in each assessment and the respective grade.

This regression showed an angular coefficient of 1.85, indicating that doubling the time spent in the platform accounts for 1.85 points in the PL activities grade. The regression further suggests that for students to achieve the minimum grade (5 points), they need to dedicate a little more than 30 minutes per assessment. With one hour of dedication, the grade already increases to 6.6 and with two hours of study, the grade reaches approximately 8.45, and a dedication of 4h is enough to get full marks. This indicates that PL activities could fit in an average student's weekly schedule.

3.3 Performance in PL activities and performance in final exam

Finally, we analyse the impact of activities done in Prairie Learn on student learning. The metric available for this evaluation is the grade in the final exam of the course. The exam encompassed all the content presented in the assessments.

The first aspect evaluated was how the number of hours spent on activities in Prairie Learn affected the final exam grade. For this, we fitted a linear regression between the total time on the platform and the score on the test. This regression shows an adjusted r-squared of 0.003 and the p-value of the time of use was 0.311. With this, it is not possible to state that there is a linear relationship between the time of use of Prairie Learn and the final grade. However, it is interesting to note that no students who engaged more than 10h with PL any grades below six (the grade for approval is five).

Next, we sought to assess the impact of the number of assessments students engaged with on the final exam grade. Similarly, the regression results were an adjusted r-squared of 0.036 and a p-value of 0.176 on the percentage of student engagement. Therefore, it is also not possible to state that there is a linear relationship between engagement with assessments and student performance in the final exam.

Finally, we analysed the relationship between the final score on Prairie Learn and the score on the exam. We present the data and regression in Figure 7.

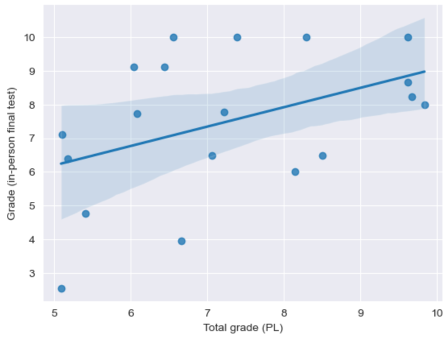

Figure 7. Linear regression between the total grade on Prairie Learn and the final exam grade.

This regression, unlike the others, indicated some correlation. The regression returned an adjusted r-squared of 0.147, a p-value of 0.059, and an angular coefficient of 0.284, thus we can state that with 10% significance, there is a positive influence of the grade obtained by the student in Prairie Learn on the final exam grade. Despite the positive influence, the score in the assessments does not fully explain the score in the final exam, which means that many other factors could impact the final grade.

4 Conclusion

Student data analysis on the use of Prairie Learn in a Data Science course revealed that engagement with take-home activities correlated with the grades in an in-person, final exam. This means that PL can be seen as an important learning environment, but it must be combined with other tools.

Also, data analysis indicated that number randomization was not enough to prevent solution sharing, which agrees with previous work (Che, 2018). Solution sharing can be related to assignments that only take a few seconds to be completed. Although this could be mitigated by using a specific room for PL exercises or by designing assessments with random questions (rather than only random numbers), it is likely that this happened because of student’s poor time management skills, meaning that it could be helpful to use shorter assignments with shorter deadlines.

5 References

Chen, B., West, M., & Zilles, C. (2018). How much randomization is needed to deter collaborative cheating on asynchronous exams? In Proceedings of the Fifth Annual ACM Conference on Learning at Scale (L@S '18). Association for Computing Machinery, New York, NY, USA, Article 62, 1–10. https://doi.org/10.1145/3231644.3231664

Moosvi, F., Eddelbuettel, D., Zilles, C., Wolfman, S. A., Fund, F., Alford, L. K., & Schroeder, J. (2023). Creating Algorithmically Generated Questions Using a Modern, Open-sourced, Online Platform: PrairieLearn. In Proceedings of the 54th ACM Technical Symposium on Computer Science Education V. 2 (SIGCSE 2023). Association for Computing Machinery, New York, NY, USA, 1177. https://doi.org/10.1145/3545947.3569634

Mustafa, A. S., & Ali, N. (2023). "The Adoption and Use of Moodle in Online Learning: A Systematic Review," Information Sciences Letters: Vol. 12 : Iss. 1 , PP -. Available at: https://digitalcommons.aaru.edu.jo/isl/vol12/iss1/29

Nip, T., Gunter, E. L., Herman, G. L., Morphew, J. W., & West, M. (2018). Using a Computer-based Testing Facility to Improve Student Learning in a Programming Languages and Compilers Course. In Proceedings of the 49th ACM Technical Symposium on Computer Science Education (SIGCSE '18). Association for Computing Machinery, New York, NY, USA, 568–573. https://doi.org/10.1145/3159450.3159500

Wintersberger, D., & Saunders, M. (2020). Formulating and clarifying the research topic: insights and a guide for the production management research community. Production, 30

West, M., & Herman, G. L., & Zilles, C. (2015, June). PrairieLearn: Mastery-based Online Problem Solving with Adaptive Scoring and Recommendations Driven by Machine Learning Paper presented at 2015 ASEE Annual Conference & Exposition, Seattle, Washington. 10.18260/p.24575

Cross-semester student-centered integration project in mechanical engineering

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Abstract: Traditional learning methods are a trademark in engineering teaching, centered on the figure of the teacher, who passes on the knowledge to the student. This teacher-centered learning creates little student participation in the classroom, affecting their interests and practical questions regarding the subjects studied. In addition, the retention of the topics by the student in this type of teaching is low, as has already been published by some authors. Since the beginning of its engineering course, Insper has focused on the student, training, and orienting its teachers to make the class much more participatory. Therefore, it allows the student to ask questions about the subject that make each class unique, depending only on how interested in a topic the students are. Working on a continuous improvement process, the professors of specific engineering semesters now pose a new challenge to the students and, naturally, to themselves. Professors have conceived cross-semester projects that allow students to apply the knowledge they acquire in each subject to practical situations, intending to increase their interest, participation, and learning. The authors present the results of the transversal project of the fifth semester of mechanical engineering, in which students simulate, manufacture and test a scale model of a wind turbine. Thus, they use their knowledge in manufacturing, machine elements, mechanical vibrations, and numerical methods. Moreover, students also develop skills necessary for their professional life, such as teamwork, communication, and project management. Consequently, the application of this transversal project has shown excellent results over the two years of its application, mainly in terms of student engagement and motivation.

Keywords: Project Based Learning, PBL, curriculum design, design, product development education

1 Introduction

The new engineering graduate must navigate a rapidly changing world loaded with new technologies and challenges. Engineers serve as agents of change in society, developing innovative products, technologies, and infrastructure (Pereira, Barreto, and Pazeti, 2017). Thus, technical knowledge alone is no longer sufficient, as engineers must acquire additional competencies, such as communication skills, to effectively convey their ideas and address globalization and lifelong learning (Lima et al., 2012; Puente, van Eijck, and Jochems, 2011).

Courses employing Project Based Learning (PBL) often offer more hands-on experiences, allowing students to tackle real-world problems (Puente et al., 2011; Sukackė et al., 2022). These courses provide an opportunity to apply multidisciplinary knowledge through semester-long projects (Kim et al., 2004; Lima et al., 2012). Some engineering schools adopt PBL-style courses to introduce students to product development, where students face different design challenges each semester (Banzaert, Ariely, and Wallace, 2006). Other schools collaborate with companies, offering students the chance to work on projects related to process optimization (Alves and Soares, 2020). Alternatively, students can engage with virtual companies, working on projects that incorporate given design requisites (Alves and Soares, 2020; Cavalcante et al., 2018). These integrative teaching strategies contribute to and enhance students' learning experience (Edström and Kolmos, 2014).

PBL-style courses can serve as integrative components within a semester, helping students develop various competencies (Alves and Soares, 2020). However, some courses lack integration with other disciplines in the same semester, resulting in students simultaneously designing, manufacturing, and testing their projects while attending lectures on different subjects like CNC machining, product development, and project management (Banzaert et al., 2006). In later semesters of a bachelor's degree program, some courses build upon previously acquired knowledge, while others seek to integrate current and past content (Cavalcante et al., 2018; Pereira et al., 2017). Nevertheless, courses developed later may not have closely related content to those created earlier (Lima et al., 2007).

Designing an engineering course with PBL as a foundational principle allows for better integration with the semester's content. In this case, the PBL course, Mechanical Design, was the first course tought in the semester. The selection of remaining disciplines for the semester aimed to provide students with the technical knowledge necessary for the development of the course's project—an intricate scale model of a wind turbine.

2 Case study context

This study describes an educational initiative implemented in a private college in southeast Brazil, Insper – Institute for Education and Research, as part of the Mechanical Engineering undergraduate course. The initiative takes place in the fifth semester of the 10-semester program and focuses on specialization in Mechanical Design. Students develop a small-scale wind turbine using a wind tunnel, with specific design criteria for size, weight, and power generation.

Therefore, to support this effort, the semester includes four courses: Mechanical Vibrations, Machine Elements, Numerical Methods, and Fabrication and Metrology. Each one has four hours per week, divided into 2-hour classes, except for Fabrication and Metrology, which has 2-hour exposition class and 2-hour lab class. Two professors work as lecturers and tutors for the Mechanical Design class (Lima et al. 2007; Puente et al. 2011). As tutors, they provide guidance on teamwork and project management. The project development is in groups of three to four students, with group assignments made in the first two weeks of the semester. Assessment includes technical background, soft skills, and motivation of each student. The main objective is to form groups with the highest potential to achieve the project goals. This course also includes two sessions of 2-hour classes per week, with 40 minutes to 1 hour dedicated to exposition and the remaining time allocated to group supervision, where the professors interact with each group individually. This structure allows for project development, exposition of project management skills, and activities.

The undergraduate engineering teaching laboratories at INSPER provide technical support for design, manufacturing, and testing. The Fluids and Thermal Sciences laboratory offers equipment for evaluating basic fluid mechanics knowledge and testing turbine performance in a wind tunnel. The TechLab manufacturing laboratory supports the construction of conceptual and functional prototypes to validate design decisions and demonstrate the turbine's primary function, primarily through CNC machines. The Projects laboratory are a collaborative base for resource sharing and project discussions, functioning as a "war room." These spaces have teaching technicians who can share experiences and provide mentorship in project knowledge, offering practical and diverse perspectives for proposing alternatives.

The evaluation process involves professors from all five disciplines participating in two project milestones. These milestones follow the Stage-Gate® Lite product development process (Cooper, 2008). They represent the concept and detail design gates, whose requirement explanation takes place during the exposition portion of the Mechanical Design class.

The team supporting this initiative consists of seven laboratory technicians, four professors from the same semester's disciplines, one teaching assistant in the manufacturing and design area, and the two professors responsible for the Mechanical Design course. The first gate focuses on concept design, while the second gate involves the final project presentation, where students showcase the results of their prototypes and simulation validations. This process allows for a comprehensive evaluation of the students' design skills, from the initial concept to the final product.

Overall, this initiative provides valuable learning experiences for the students, allowing them to apply their theoretical knowledge to a real-world project. It also facilitates the development of crucial skills such as project management, teamwork, and problem-solving. This study emphasizes the importance of implementing practical, hands-on initiatives to complement theoretical education.

3 Interdisciplinary description

In recent years, Problem-Based Learning (PBL) courses have gained popularity in engineering education. These courses challenge students to design and manufacture their projects. However, many of these courses are not fully integrated into the curriculum, resulting in a lack of connection to other disciplines and limited access to knowledge beyond the specific course material.

At Insper, we have taken a different approach by designing our Mechanical Engineering curriculum with an integrated project at its core. In the fifth semester, the Mechanical Design class focuses on product development and management, with technical subjects provided by other disciplines in the same semester (Fig. 1). Professors serve as tutors, guiding the students through the project, with lecture time dedicated to group work on the projects.

The project assigned in the Mechanical Design class involves designing, simulating, manufacturing, and testing a wind turbine that adheres to specific parameters. This project allows students to apply the knowledge gained throughout the semester to a real-world problem while developing crucial skills in collaboration, project management, and critical thinking.

This integrated approach to project-based learning provides the students with a unique and valuable experience, enabling them to draw upon a broad range of knowledge and skills to solve complex engineering problems. By combining technical subject matter with hands-on projects, we are preparing our students for successful careers in a rapidly-evolving field.

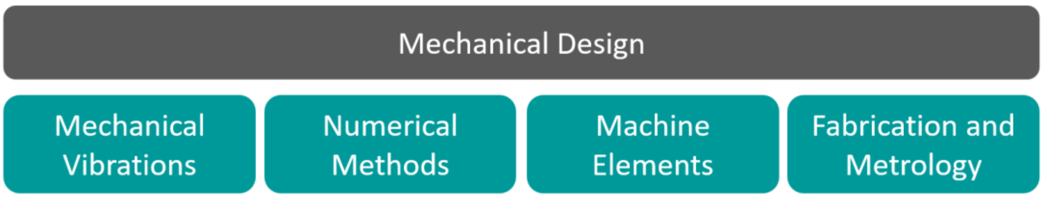

Figure 1 – Mechanical engineering semester structure

Design project integration in engineering curricula has become increasingly popular in recent years, mainly through Problem-Based Learning (PBL) courses. However, in many cases, these projects are not fully integrated into the semester curriculum and can lack connections to other disciplines. Therefore, it can limit students' ability to apply knowledge gained outside the project in question.

At Insper, we have taken a different approach. From the outset, we designed our Mechanical Engineering curriculum to include an integrated project as the lead theme of the semester. In the fifth semester, students take a Mechanical Design class focusing on product development and management. The class places little emphasis on traditional lectures, as other courses provide technical subjects. Instead, professors serve as project tutors, and students use lecture time for group work on their projects.

The project in question involves designing, simulating, manufacturing, and testing a scale model of a wind turbine that meets specified design parameters. These include initial wind velocity for rotor rotation, power generation, vibration range, and cost. In addition, students must perform Finite Element Analysis (FEA) to ensure structural rigidity with minimal deflection when wind force is applied.

The project has three key learning goals: technical design, project management, and teamwork. The technical design goal involves developing mechanical concepts, sizing, detailing, prototyping, validating, and documenting the mechanical device design. Project management requires product-developing process tools and practices to manage the mechanical device design. Finally, teamwork involves identifying and enabling the roles and responsibilities of all team members, ensuring their engagement.

While other courses in the semester teach the content required for technical design, such as Mechanisms and Machine Design, the Mechanical Design class provides students with the technical fundamentals needed for material selection, calculation of minimum dimensions and sizes of structural components, as well as the choice of machine components such as screws, bearings, and couplings.

Furthermore, all courses in the semester benefit from this integration, as the real problem presented reinforce development. To provide technical support for the wind turbine project, we included a class on machine elements in the semester. The rotor speed range and resulting vibration caused by the propeller are crucial aspects that require students to have a solid foundation in mechanical vibrations. Therefore, the semester includes a dedicated lecture on vibration theory, simulation, and validation testing. After manufacturing the prototype, students analyze its vibration modes using a hammer test and compare them with the simulation results.

Understanding the techniques used to solve simulations is as essential as the simulations themselves. To enhance students' comprehension of simulations and enable them to utilize these methods in other areas of study, such as Machine Elements, we included a Numerical Methods class in the semester.

Following the Stage-Gate® Lite product development process (Cooper, 2008) (Fig. 2), professors evaluate students in two design gates, with the first one taking place at the semester's midpoint. During the 20-minute presentation, a board consisting of at least one professor from each of the other classes evaluates the students' initial CAD designs and FEA simulations. Students also present their project scope, the Work Breakdown Structure (WBS), the proposed schedule, and each student's responsibility with a Gantt chart. Expert professors assess each technical aspect of the presentation and evaluate the project planning.

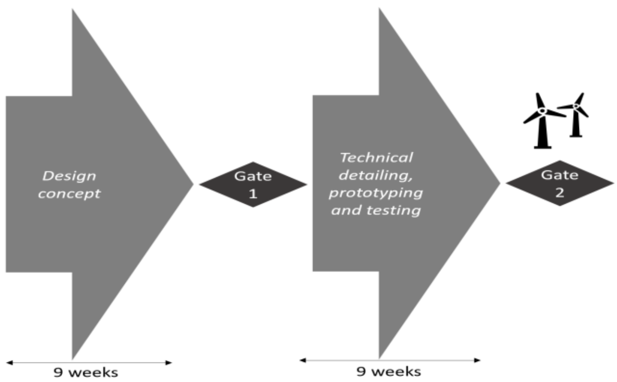

Figure 2 – Product development process based on stage gate adapted from: (Cooper 2008)

Students re-work their model based on feedback received during gate presentations after the first design gate in the Mechanical Design class, proceeding afterwards with prototype manufacturing. Precision is crucial because the wind turbine is on a small scale. Hence, students must design and manufacture the mechanical components with great care, ensuring the free movement of the rotor axle with minimal effort. To help students achieve this level of precision, we added a Fabrication and Metrology class covering GD&T, good practices in mechanical design drawings, and CNC manufacturing, emphasizing CAM programming. Students apply this knowledge to manufacture their designed parts and assemble them.

Once the students complete the prototype, they test it in a wind tunnel when they assess all remaining design requirements. For example, the rotor must rotate at a minimum wind velocity of 8 m/s and generate a minimum of 12 V electricity at 18 m/s. Finally, in the second gate, students present their final version of the functional prototype, CAM strategies, FEA analyses, and the validation results of vibration modes and power generation. At this stage, the wind turbine concept tends to meet the gate deliverables, such as product layout, bill-of-materials, CAD part and assembly, technical drawings, and product structure and main functions solutions.

In conclusion, this multidisciplinary wind turbine project allows students to apply the technical knowledge and project management tools learned throughout the semester. It also emphasizes the significance of teamwork, involving the identification and enablement of the roles and responsibilities of all team members, ensuring their engagement and collaboration to achieve common goals.

4 Results

As shown in Fig. 3 (class of 2022), the students conducted a simplified simulation in Siemens NX, measuring the natural frequency at approximately 58.2 Hz. To validate the simulation, they performed a hammer test in the blue regions illustrated in Fig. 3, with the sensor positioned in the red area. The measured natural frequency was 55.6 Hz, indicating an error of 4.5% between the experimental and simulation values, with a damping coefficient of 21.7%.

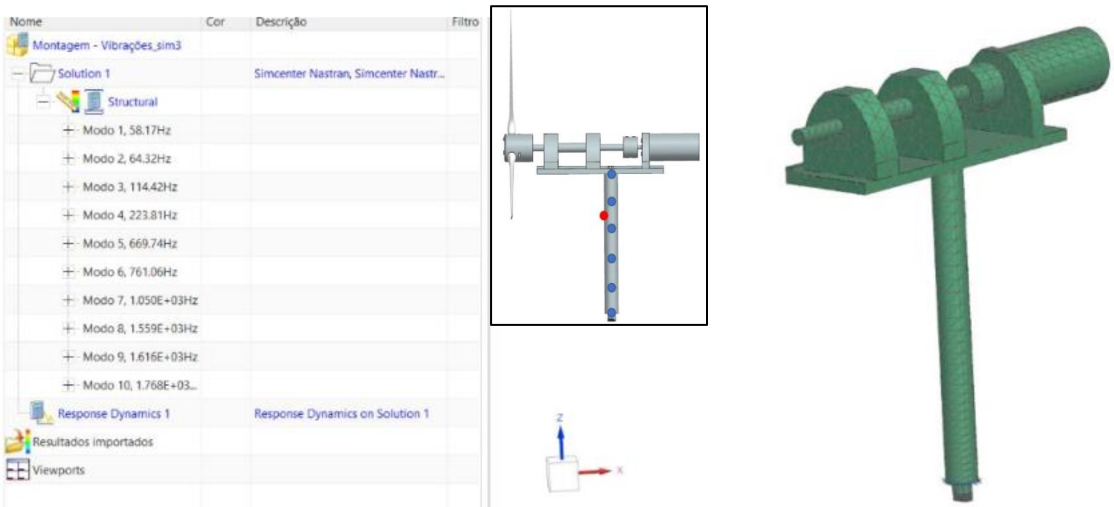

Figure 3 - Vibration mode simulation in Siemens NX, and Hammer points in blue and sensor position in red for vibration validation

The results revealed that the assembled turbine's natural frequency exceeded the maximum frequency work range by more than two times. Additionally, the prototype's weight, as shown in Fig. 4, was measured at 2.4 kg, which is below the design requirement of 4 kg. The manufactured prototype used CNC machining and additive manufacturing for the rotor and blades. It withstood a wind velocity of 20 m/s and generated a total power of 1.3 V at 12 m/s.

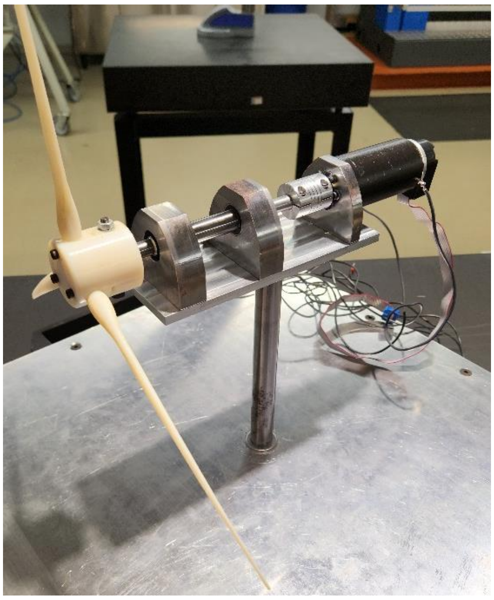

Figure 4 – Prototype of the Wind Turbine fully assembled.

In summary, the prototype met the design requirements and demonstrated satisfactory results for natural frequency, weight, and power generation. The utilization of Siemens NX simulation software and the application of CNC machining and additive manufacturing processes contributed to the successful development of the prototype. The feedback and appraisal received from the management board aided in improving the design solution and validating the prototype results.

5 Conclusion

This paper presents an interdisciplinary project for the Mechanical Design discipline to integrate technical content from four other courses in the fifth semester of the Mechanical Engineering undergraduate course. The lectures in the four specialties provide the necessary technical knowledge for prototype development. The project follows a Problem-Based Learning (PBL) approach to promote the integration of multidisciplinary technical content, teamwork, and project management competencies.

Students face a significant workload as they must meet the deadlines for the project and other commitments, such as tests in other courses. However, by the end of the semester, they gain an intrinsic understanding of product development as a multidisciplinary activity. The students learn to design a product that meets all the design requirements and can be manufactured and tested with high fidelity.

Despite the project's success, there is currently no measure of students' knowledge retention. Therefore, future work should focus on evaluating students' perceptions of the content and the integration of disciplines.

6 References

Alves, Anabela C., and Filomena Soares. 2020. "Interdisciplinary Contents Integration and Key Competences Developed in a Project Work of Industrial Engineering and Management Third Year." Pp. 21–30 in International Symposium on Project Approaches in Engineering Education.

Banzaert, Amy, Sumedha G. Ariely, and David R. Wallace. 2006. "Incorporating Open-Ended, Service-Oriented Projects into a Senior Product Design Class: Methodology and Outcomes." Proceedings of IDETC/CIE 2006 ASME 2006 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference 10–13.

Cavalcante, Koike, M. C. Carla, Dianne M. Viana, and Flavio B. Vidal. 2018. "Mechanical Engineering, Computer Science and Art in Interdisciplinary Project-Based Learning Projects." International Journal of Mechanical Engineering Education 46(1):83–94.

Cooper, Robert G. 2008. "Perspective: The Stage-Gate s Idea-to-Launch Process-Update, What's New, and NexGen Systems." The Journal of Product Innovation Management (25):213–32.

Edström, Kristina, and Anette Kolmos. 2014. "PBL and CDIO: Complementary Models for Engineering Education Development." European Journal of Engineering Education 39(5):539–55. doi: 10.1080/03043797.2014.895703.

Kim, Il Yong, Olivier De Weck, William Nadir, Peter Young, and David Wallace. 2004. Innovative Modern Engineering Design and Rapid Prototyping Course: A Rewarding CAD/CAE/CAM Experience for Undergraduates.

Lima, Rui M., Dinis Carvalho, Maria Assunção Flores, and Natascha Van Hattum-Janssen. 2007. "A Case Study on Project Led Education in Engineering: Students' and Teachers' Perceptions." European Journal of Engineering Education 32(3):337–47. doi: 10.1080/03043790701278599.

Lima, Rui M., João Mello Da Silva, Natascha Van Hattum-Janssen, Simone Borges, Simão Monteiro, João Carlos, and Félix De Souza. 2012. Project-Based Learning Course Design: A Service Design Approach. Vol. 11.

Pereira, Marco Antonio Carvalho, Maria Auxiliadora Motta Barreto, and Marina Pazeti. 2017. "Application of Project-Based Learning in the First Year of an Industrial Engineering Program: Lessons Learned and Challenges." Production 27(Specialissue). doi: 10.1590/0103-6513.223816.

Puente, S. M. Gómez, M. V. van Eijck, and W. Jochems. 2011. "Towards Characterising Design-Based Learning in Engineering Education: A Review of the Literature." European Journal of Engineering Education 36(2):137–49.

Sukackė, Vilma, Aida Olivia Pereira de Carvalho Guerra, Dorothea Ellinger, Vânia Carlos, Saulė Petronienė, Lina Gaižiūnienė, Silvia Blanch, Anna Marbà-Tallada, and Andrea Brose. 2022. "Towards Active Evidence-Based Learning in Engineering Education: A Systematic Literature Review of PBL, PjBL, and CBL." Sustainability (Switzerland) 14(21).

A case study on Project-Based Learning applied to industrial automation and production systems

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Abstract

Project-Based Learning (PBL) is a methodology widely used in undergraduate courses, where learning objectives are achieved through a project developed by students. In PBL, course content and skills are actively constructed by students based on inquiries and problem solving, which are closely linked to real-life problems. Industrial automation is a constantly evolving field and a reality in modern enterprises in the form of assembly lines, system integration, and process management. Industrial automation projects are mostly custom-made for each company culture, type of product or service and many other characteristics. Teaching industrial automation is particularly challenging due to the integration of various areas, like mechanics, electric/electronics, networking, programming along with students' soft skills like communication, leadership, conflict resolution, time management, etc. With the aim of exposing students to the reality of an industrial automation project and at the same time developing their soft skills, we propose the integration of 3 support courses to a practical industrial automation project. The project is described as a partially simulated assembly line connected to a real servo-positioning pick-and-place where the students must integrate, manage the flow of products along the line and assimilate various concepts of automation, like quality control, traceability, supervision, and financial aspect of an assembly line. The devices, software systems, controllers, sensors, and networks are the same often found in real-world automation projects. The project is developed by groups of 3 to 5 students, and, to monitor the students' development, we establish milestones throughout the semester, which are assessed both by group and individuals' competences. The soft skills are assessed by 360-degree feedback and the learning-to-learn skills are assessed by individual tasks, where the students face new problems to apply them in the project.

Keywords: Project-based Learning; Engineering Education; Industrial Automation.

1. Introduction

Project-based learning (PBL) can be defined as an activity in which students develop an understanding through some kind of involvement in an actual (or simulated) real-life problem or issue and in which they have some degree of responsibility in designing their learning activities (Morgan, 1983). PBL has been used in the late Renaissance in the architecture schools of Italy (1590–1765) and, nowadays, this educational approach has been recognized for many years throughout the world, from elementary schools to universities (Fallik et al., 2008).

PBL provides a learning environment where engineering students can collaborate in multi-disciplinary, geographically-distributed teams on project-centered activities that produce a product for an industry client. In PBL, cross-disciplinary learning is conducted which is a journey from the state of island of knowledge (discipline-centric) to a state of understanding of the goals, language, and representations of the other disciplines. Students learn through solving problems and reflecting on their experience (Otake et al., 2009).

Automation (common examples are process, product and building automation) is a constantly evolving field and a reality in any modern enterprise in the form of assembly lines, system integration, quality control, safety and reliability, and process management. Industrial automation projects are mostly custom-made for each company culture, type of product or service, considering regional differences and many other characteristics.

Teaching industrial automation is particularly challenging, due to the integration of various areas, like mechanics, electric/electronics, networking, programming along with students' soft skills like communication, leadership, conflict resolution, time management, etc. Teaching industrial automation using the project-based learning (PBL) approach is considered as one of the most effective tools used in engineering education (Salewski et al., 2015).

This case study is based on the experience with the course of Automation Project Design at INSPER, in São Paulo – Brazil. The course of Automation Project Design is part of the *Thematic Period* called Industrial Automation and comprises mostly of the 6th period (6th semester) of the curriculum in the Mechatronic program. The course of Industrial Automation Project Design has an *Integrating Project* which is supported by others regular curses, like Industrial Automation and Electrical Machines and Drives and other elective courses chosen by the students, for example Integrated Manufacturing Planning, Machine Vision, Engineering Analytics.

The rest of the paper is organized as follows: Section 2 presents the thematic periods and how the integrating project provides an integrating student journey along the period. In Section 3 is presented the setup of the industrial automation laboratory and in Section 4 the dynamic of the course and how the PBL is conducted. In Sections 5 and 6 it is presented the assessments and the results of the course and the PBL approach, followed by conclusions in Section 7.

2. The Industrial Automation Thematic Period

INSPER's Engineering programs are based on teaching techniques that focus on practical experiences and in-depth discussions of interdisciplinary cases to sustain proactivity and professional improvement of the students. This approach becomes more evident between the 5th and 7th periods. On each of those periods, there is an *Integrating Project* that poses a challenging project within the academic theme to be developed in that period. On each *Thematic Period*, there are supporting courses that are important to develop essential technical skills for solving the problems that appear. Other related topics are also inserted, which seek to integrate other areas of INSPER and encourage interdisciplinary discussions, which includes vertical and horizonal integration of the students.

In order to successfully conclude the *Integrating Project* in the course of Automation Project Design, it is also important to develop and demonstrate interpersonal skills, like the ability to work in groups and have results orientation. This is achieved by alternating group and individual milestones where the students have to present competences and then integrate them, successively. With such an approach the students have to plan, negotiate, execute and informally evaluate each other's evolution. The formal assessment will be discussed in the sequel.

Working in groups showing the ability to communicate and present ideas is one of the Program Educational Objectives (PEOs) of the Mechatronic Program, which are reinforced in the context of the *Integrating Project*s of the 5th to 7th periods. The course of Automation Project Design is specially assessed by following Student Outcomes (SOs):

- D&E! – Design and Entrepreneurship;
- CO – Communication; and,
- TW – Teamwork.

Applying the above principles, on the 6th period and during Automation Project Design, the students should conceive, model, assemble, program, virtually commission and validate a production line of a *thematic product*, where the assembly line is merged by virtual parts and real parts. In this context, programming skills for industrial controllers and supervisory systems are developed, as well as project management, industrial operations management, financial viability of projects.

Together with the Automation Project Design, two other associated disciplines share the development of technical competences in automation, as seen in the Figure 1. The course of Industrial Automation is responsible for introducing automation concepts, teaching sensors and instrumentation principles, industrial networks, and their communication protocols, in addition to one of the main industrial actuator mechanisms: pneumatics/hydraulics. The course of Electrical Machines and Drives is responsible for discussing the types and choice of electric motors and the design of their power drives.

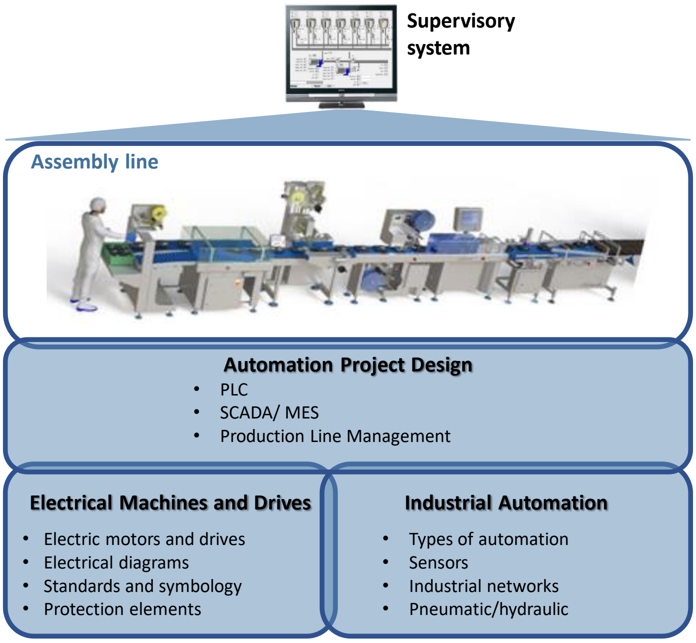

Figure 1. Industrial Automation *Thematic Period*, consisting of an *Integrating Project* and two supporting courses.

To gain engagement, it is used aspects of the gamification, like performance metrics, multiple-criteria decision and production pressure, the same metrics commonly used in the real problem of restrictions in the context of manufacturing. Thus, we seek to simulate the dynamics of a typical engineering sector, including its jargon, principles, conflicts, and pressures.

One of the challenges to provide a truly engaging student's experience is the horizontal integration between the 6th period courses. This is achieved with meetings at the beginning of each period where the participants, professor and supporting technicians, discuss the sequence and the timing of the themes. The table below provides short view of this synchronism between disciplines.

Table 1. Alignment between the courses for the integrating project.

Timing (example)	Automation Project Design	Industrial Automation	Electrical Machines and Drives
Classes 1-3; 16/Aug - 23/Aug	Case study and production line management	Types of automation	Concepts of electric motors and drives, laboratory safety procedures
Classes 10-12; 20/Sep - 11/Oct	Motion control and network interfaces between field devices	Industrial networks	How to apply motion profile to servomotors

Classes 13-15; 18/Oct - 25/Oct	Practice with PWM in PLCs, Programming analog inputs and high-speed counting	Sensors, transducers, and encoders	Understanding electrical diagrams, symbology, and terminology
Classes 17-20; 26/Oct - 9/Nov	Design of the testing station	Fluid power and pneumatic	Standards, protection elements, electrical wiring, special motor topics

3. Setup of the industrial automation laboratory

To experience a production line scenario that emulated the real world, all the equipment and systems provided by the industrial automation laboratory are the same often found in professional automation projects. Some of the equipment is pre-assembled in didactic rigs to guarantee the electrical safety of the systems.

A list of the main hardware available in the laboratory is presented below:

- Programmable logic controller (PLC Siemens S7-1200)
- Human-machine interface (HMI Siemens Touch 7")
- Remote Terminal Units (RTUs B&R with Profibus and ProfiNET interfaces)
- Electric motors e Driver (induction motor, servo motor and stepper motor)
- Pneumatic workbench with multiple types of cylinders and valves (Festo)

The software systems are presented below:

- Programming platforms for the PLC and HMI (Siemens TIA Portal)
- Programming platforms for the supervisory system (Elipse E3)
- Commissioning Software for the electric drivers (Sinamics V-Assistant)
- Simulation environment for pneumatic and hydraulic circuits (Festo FluidSIM)
- Factory simulation/virtualization software (Factory IO)

4. The dynamics of the automation project

Any real production line project design, as well in the *Integrating Project*, starts with the conception phase, based on the type of product that should be produced, production capacity and key production parameters, from where it is defined the key equipment and its quantity, the production layout with their product flow and main area of storage. In addition, operational safety issues must always be considered, mainly in compliance with the *Workplace safety standards* (NR12 in Brazil). At this phase, it is important to consider several scenarios to maximize the overall performance of the line. Once conceived, the production line goes through manufacturing, programming (if it has automatic operations) and later validation of the entire process. The last phase comprises the technical criteria related to product assembly, as well as the line performance criteria and the financial criteria. All those criteria are evaluated by rubrics and checklists. The same sequency of phases, outcomes and deliverables were implemented in the Automation Project Design course.

Students carry out the project in groups of 3 to 5 students. It is given for the groups a description of a challenge to be met throughout the course, starting with how the raw material arrives in the production line, what are the intermediate processing rules and how is the final shipping format. All groups initially start from an empty area or warehouse, from which they must build their virtual factory. The Figure2 presents the initial image of the production line virtualization software (an empty warehouse).

Figure 2. Empty warehouse, from which they must build their virtual factory.

From this point on, the project discipline dictates the rhythm of deliveries throughout the semester, marked by Design Phases. Each phase ends up in a Design Gate, which represent key points in a project where a formal review of the project's current state is performed. Below is a description of each of the 3 design phases proposed and the expected list of outputs to be presented in the gates.

In *Phase 1*, the group should freely conceive possible production line scenarios, created from an extensive list of available equipment in the virtualization software FactoryIO. However, a price list for each component is provided, so the group must propose scenarios and estimate the initial investment. The group is requested to conduct a financial analysis of this investment, taking into consideration the estimated production volume and the costs and expenses provided in the project description (raw material costs, manufacturing costs, labor expenses, taxes, etc). One important restriction is the limited market size, which finely results in the takt time.

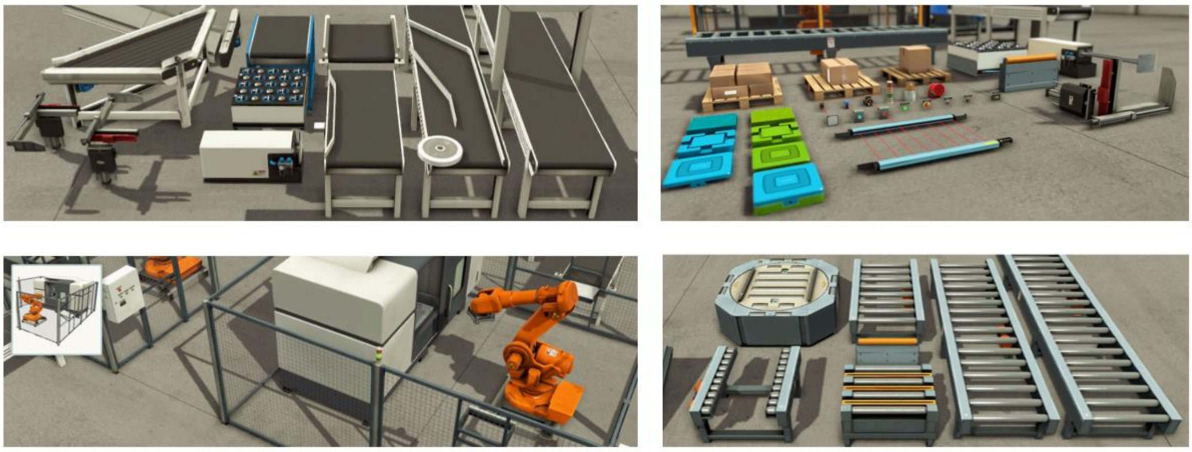

Figure 3. Picture of the devices and equipment available in the software to conceive the virtual production line.

At the Gate 1, it is expected that each group being able to present the feasible scenarios and justify the chosen one based on an analysis of the economic viability indicators of the investment, measured through Net Present Value (NPV) and Internal Rate of Return (IRR).

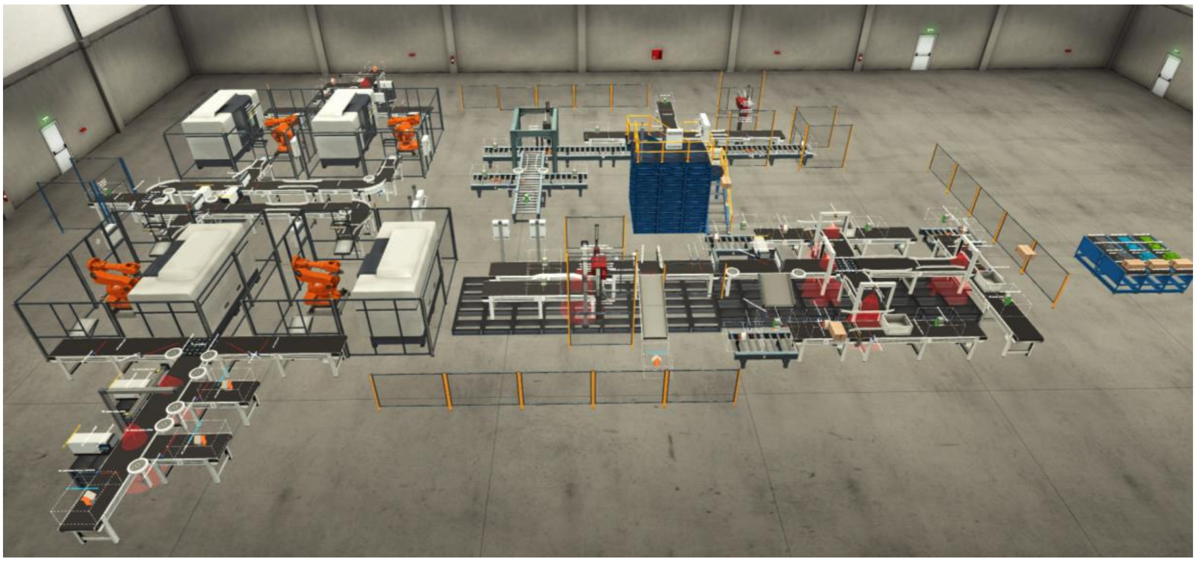

Figure 4. Example of a virtual production line conceived by the students.

After the successful validation of the chosen scenario, the group moves on to *Phase 2* of the project. In this phase, the production line is divided into workstations (e.g., machining, assembly, packaging, palletizing...), and each group member is responsible for programing the PLC for their respective workstation. In this phase, the programming competency is assessed individually, as well the ability to work and communicate as a team, as each workstation must respect the signals and control interfaces. For example, if a workstation is waiting for a digital input signal from a previous workstation that indicates the status of a part, the coherence of the project is checked if the previous workstation is properly sending this signal.

At the end of *Gate 2*, each student must deliver the PLC programming software, as well as complete documentation of the code (programming flowchart and/or state machine diagram, internal memory flags and I/O tags, and interface signal map).

Finally, in *Phase 3* of the project, the integration of individual workstations takes place, returning the initial assembly line concept, as conceived in *Phase 1*, but now with all workstations operational and properly programmed. At this point, interface failures often arise, and they need to be corrected. This is followed by continuous improvement of the operation logic to achieve better productivity of the production line. In parallel to this improvement work, the group proceeds to implement a supervisory system, through which is possible to visualize and control the entry of raw materials, work-in-process inventory, final product output and other indicators necessary for the proper operation of the factory.

However, in this phase, the group should start the assembly and programming of another important part of the project: the physical testing station (see Figure 5), which is provided to the students with a checklist on how it should work, mandatory and desirable functionalities and quality criteria. This is another significant portion of the project and involves developing additional practical automation skills, such as installation of the electrical circuit, setting the communication wiring and configuration of the communication networks, debugging of the connection errors, commissioning of the servo driver, pneumatic design and installation of its devices, adjustment of control parameters, etc.

The physical testing station consists of a cartesian motion system, with a horizontal axis (X axis) driven by a servo motor and coupled to a trapezoidal spindle, and a vertical axis (Z axis) composed of a double-acting pneumatic cylinder. Attached to the Z axis, a resistive displacement transducer is responsible for measuring and validate the thickness of a testing part. Thus, at a given point in the virtual assembly line, the virtual part stops, and its movement is defined by the physical testing station, where a physical sample is tested, and the approval or rejection signal is sent back to the line controller. If approved, the virtual part continues with the assembly process. However, if rejected, the virtual part should be diverted to a lateral conveyor for disposal.

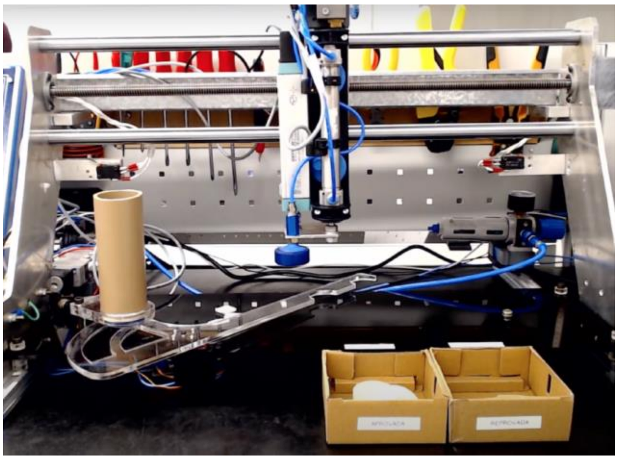

Figure 5. Picture of the physical testing station.

At *Gate 3*, the entire assembly line must be fully programmed and functional, with testing station integration and monitored by a supervisory system. The assessment of this final Gate is described in the following section.

5. Assessment of the Integrated Semester

The automation design project is also evaluated with other associate courses of the semester, in an integration manner. Thus, in *Gate 3*, the assessment of technical competencies is mostly carried out by partner courses.

Table 2: Competencies assessed by the associated technical courses.

Industrial Automation	Electrical Machines and Drives
Sensor selection and installation	Draw of the electrical diagram
Calibration of the displacement sensors	Motor selection for the horizontal axis
Configuration of industrial networks for PLC, HMI, RTU and servo driver	Commissioning of a servo driver
Selection and assembly of pneumatic circuits (vertical axis)	Auto tunning of a servo driver

The overall results achieved by the project are measured through 3 criteria, which again follow the real validation process of any production line. These criteria are: i) safety; ii) productivity; and iii) financial viability. Thus, in the week prior to the project delivery, a safety TRYOUT of the test station is carried out. In this event, the test station must comply with a checklist of safety items according to the applicable standards for the equipment (Brazilian standard NR12).

With the group's approval in the TRYOUT (all safety items were passed) proceed to the final day of the semester, where the *Automation Contest* takes place. With a spirit of motivation and achievement rather than competition, the groups run their production lines for a period of one hour, during which performance indicators are measured to validate the entire project and consequently approve the students in the course. For the productivity metric, we use the same standard indicator used in factories to measure machine and process effectiveness: Overall Equipment Effectiveness (OEE) (Slack et al., 2010). For the financial metric, we use the same economic evaluation presented in *Gate 1* (Net Present Value and Internal Rate of Return), but now using the actual production volume measured within the 1-hour. The group is passed if they were passed in the TRYOUT (safety items) and achieved the chosen minimum success indicators: an OEE index higher than

35% and a positive Net Present Value. Once approved, we move on to the second objective of the contest day: the group that achieves the best performance index wins the Contest.

In addition to the group's performance, which must meet the essential requirements for the proposed project or service, each student is evaluated based on their individual performance in the project. Teamwork, communication and as well aspects such as attendance, proactivity, collaboration, and mediation are assessed by the instrument 360-Degree Feedback (McCarthy and Garavan, 1999).

6. Results and Discussions

Several Student Outcomes (SOs) are assessed in the Automation Project Design course. In addition to the Technical Knowledge (TK), it is assessed also Design and Entrepreneurship (D&E!), Communication (CO), Teamwork (TW) and Learning to Learn (L2L). In the Automation Project Design course, SOs are comprised of a set of performance indicators, as follows:

- D3: "Assess technical, market and economic feasibility of the different alternatives and implement the solution, mobilizing resources and people for this purpose".
- CO1: "Transmit and express ideas, concepts and information, verbally, visually, and in writing in an appropriate way to the target audience".
- TW1: "Contribute to a team, fulfilling the tasks assigned to its function with quality and adding value to the result of the work, preserving the team's relationship."
- TW2: "Interact with teams, encouraging colleagues to participate, showing interest in their contributions and feedback, and ensuring that members understand each other.
- TW3: Motivate the team to commit to the result of the work, seeking high quality.
- L2L2: Evaluate learning based on feedback from others, experience, and reflection.

The general grade scale in Brazil is mostly 0-10 with one decimal place.

The Performance Indicator D3 is assessed by the *Gate 1* (Project Conceptualization), where in 2023, all 23 students have received grade above 7. This is considered a desirable result (no more than 20% of students are below the grade of 5.0).

The Performance Indicator CO1 is assessed by the *Gate 3* (Project Documentation and Presentation), where in 2023, 83% received above 7 and 4% received grade below 5. This is considered a desirable result.

The Performance Indicators TW1, TW2 and TW3 are assessed by the *Gate 1* (Project Conceptualization) and the 360-Degree Feedback. In 2023, 91% of the students received grade above 7 and 4% of the students received grade below 5. This is considered a desirable result.

Finely, The Performance Indicators L2L, is assessed by the 360-Degree Feedback with the same results already presented before.

7. Conclusion

We have presented a case of applying the PBL for the course of Automation Project Design, which is presented as a complex, open-ended problem which is very close to real problems on designing production line or processes. After some modifications, we have used this approach to 5 undergraduate classes with some adjustment due to the pandemic and variations on the group sizes.

From both student feedbacks and the professor evaluations carried out by the faculty, we have received positive and fruitful suggestions. The results of the National Student Performance Examination (Enade) (Gomes et al., 2020) regarding to questions related to industrial automation, we have seen a high degree of success by the students, which indicates the retention of knowledge, because the examination is carried out at least one year after the Industrial Automation *Thematic Period* (6th period).

8. References

Fallik, O., Eylon, B. S., & Rosenfeld, S. (2008). Motivating teachers to enact free-choice project-based learning in science and technology (PBLSAT): Effects of a professional development model. Journal of Science Teacher Education, 19(6), 565-591.

Morgan, A. (1983). Theoretical aspects of project-based learning in higher education. British Journal of Educational Technology, 14(1), 66-78.

Otake, M., Fukano, R., Sako, S., Sugi, M., Kotani, K., Hayashi, J., ... & Sato, T. (2009). Autonomous collaborative environment for project-based learning. Robotics and Autonomous Systems, 57(2), 134-138.

Salewski, F., & Schmidt, R. (2015, October). Teaching industrial automation: An approach for a practical lab course. In Proceedings of the WESE'15: Workshop on Embedded and Cyber-Physical Systems Education (pp. 1-7).

Christie, M., & de Graaff, E. (2017). The philosophical and pedagogical underpinnings of Active Learning in Engineering Education. European Journal of Engineering Education, 42(1), 5-16. doi:10.1080/03043797.2016.1254160

Edström, K., & Kolmos, A. (2014). PBL and CDIO: complementary models for engineering education development. European Journal of Engineering Education, 39(5), 539-555. doi:10.1080/03043797.2014.895703

Graaff, E. d., & Kolmos, A. (2003). Characteristics of Problem–Based Learning. International Journal of Engineering Education, 19(5), 657-662.

Graaff, E. d., & Kolmos, A. (Eds.). (2007). Management of Change: Implementation of Problem-Based and Project-Based Learning in Engineering. Roterdam: Sense Publishers.

Helle, L., Tynjälä, P., & Olkinuora, E. (2006). Project-Based Learning in Post-Secondary Education - Theory, Practice and Rubber Sling Shots. Higher Education, 51(2), 287-314.

Lima, R. M., Andersson, P. H., & Saalman, E. (2017). Active Learning in Engineering Education: a (re)introduction. European Journal of Engineering Education, 42(1), 1-4. doi:10.1080/03043797.2016.1254161

Slack, N., Chambers, S., & Johnston, R. (2010). Operations management. Pearson education.

Lima, R. M., Dinis-Carvalho, J., Flores, M. A., & Hattum-Janssen, N. v. (2007). A case study on project led education in engineering: students' and teachers' perceptions. European Journal of Engineering Education, 32(3), 337 - 347.

Gomes, A. C. D. N., Madani, F. S., Maia, J. E. B., Pereira, M. C., & de Queiroz, M. H. (2020). Contributions of ENADE to the Assessment of Control and Automation Engineering in Brazil. IEEE Transactions on Education, 64(2), 124-132.

McCarthy, A. M., & Garavan, T. N. (1999). Developing self-awareness in the managerial career development process: the value of 360-degree feedback and the MBTI. Journal of European Industrial Training, 23(9), 437-445.

Powell, P. C., & Weenk, W. (2003). Project-Led Engineering Education. Utrecht: Lemma.

Active Learning Methodology in Mechatronic Project Education: A Case Study

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Abstract

Mechatronic projects are a highly interdisciplinary engineering field requiring the knowledge integration from various areas of expertise, including mechanics, electronics, computer science, and control systems. Successful development of complex machines in this field depends on a correct application of product development process (PDP) methodologies. Educational approaches that effectively prepare engineering students with the necessary skills to work in multidisciplinary teams and apply product development process methodologies in real-world scenarios present a significant challenge for engineering educators. Project-based learning (PBL) is an active learning concept that promotes the transfer of theoretical knowledge into practical application. This study presents a case of project-based learning applied in the mechatronic project course for third-year engineering undergraduates in mechatronics at INSPER-São Paulo/Brazil. The course goal is to enable teams of students to complete mechatronics projects by applying product development process methodology. The paper details the dynamics of the mechatronic project course and its integration with the other courses of the semester. It also describes the use of assessment tools to measure student performance. Undergraduate students at different stages of their academic journey participated in a survey to assess the effectiveness of active learning strategies. The survey also included those students who had recently completed the course and those who were in the final stages of their capstone project. The intended outcome of this course is for students to develop a practical and theoretical understanding of mechatronics while working on group projects. Moreover, they also must improve their interpersonal and communication skills required to work in a highly interdisciplinary field.

Keywords: Active Learning; Project-Based Learning; Mechatronic Project; Product Development Process.

1 Introduction

The development of mechatronic systems requires a multidisciplinary approach that integrates knowledge from different areas, including machine elements, manufacturing, numerical methods, and electronic systems (Casner, Renaud, Houssin, & Knittel, 2012). However, in an engineering course degree such background is teach separated in courses, not supporting the integration into a real-world activity (Copot, Ionescu, & Keyser, 2016). In this paper, we present a case study of a mechatronic project that involved the development of a concept mechatronics equipment. The project aimed to explore the use of active learning techniques in the product development process, to enhance the students' learning experience and promote the acquisition of competencies required for future engineering practice.

The concept machine was designed to be a versatile and affordable system that could be used for a particular task, in this case, a desktop robot to process automatic pipetting tasks. The project involved a group of undergraduate students from the same engineering semester, who worked together in a collaborative and iterative process to design, build, and test the machine. The product development process (PDP) was guided by the use of active learning techniques, which allowed the students to engage in problem-solving activities, reflect on their learning, and apply their knowledge in real-world situations.

In this paper, we describe the PDP used in the mechatronic project, highlighting the role of active learning in promoting the students' learning experience. We detail the dynamics of the mechatronic project course and its integration with the other courses of the semester. Finally, we describe its learning objectives and assessment methods and evaluates the effectiveness of the active learning methodology in the context of this mechatronic project course.

2 The Scenario

This study presents a case of project-based learning applied in the mechatronic project course for third-year engineering undergraduates in mechatronics at INSPER-São Paulo/Brazil. The course goal is to enable teams of students to complete mechatronics projects by applying product development process methodology.

Therefore, the mechatronic project course was planned to have a certain number of activities for a set of the Student Outcomes (SO): SO1 - Apply PDP (Product Development Process) concepts for the management and development of mechatronic products, SO2 - Design mechanisms and dimension mechanical elements of mechatronic systems, SO3 - Program microprocessor routines for mechatronic design applications, and SO4 - Design analog and digital circuits to interface with microprocessor systems.

The other 5th semester courses also cover these learning objectives, in greater detail, as shown in Table 1. The mechatronic project course focuses on exploring these learnings in a more applied way and, additionally, presents PDP concepts and tools (SO1). Thus, this course is considered an integrating course of the semester.

Table 1. Semester Courses and Student Outcomes.

Semester Courses	**Mechatronic Project course Student Outcome**			
	SO1	SO2	SO3	SO4
Mechatronic Project	■	■	■	■
Electronic Systems and Microprocessors			■	■
Machine Elements and Mechanisms		■		
Manufacturing and Metrology		■		
Numerical Methods			■	

The course's dynamics also seek to meet the following complementary objectives: teamwork, learning to learn and communication.
Carefully choosing a project to achieve these objectives is paramount, as it requires the balanced application of the areas of knowledge involved in a mechatronic project: mechanics, electronics, and software.
To ensure proper execution of PDP steps and to accommodate the time constraints of the course, they are defined from the Conceptual Project conception to the elaboration of a Functional Prototype. Tools are presented and applied for each stage of the PDP. We adopt the Guideline VDI 2221 (VDI 2221, 1993) and the tools suggested by Pahl, Beitz, Feldhusen, & Grote, 2005 as a reference for the project.

Figure 1 shows the stages proposed by the Guideline VDI 2221 (VDI 2221, 1993). The stages explored in the course are highlighted in red, with events (GATES) for presenting the results:

GATE 1: To finish the Phase II - Conceptual Design
GATE 2: To finish the Phase III - Preliminary Design: Project Documentation
GATE 3: To finish the Phase III - Preliminary Design: Physical Prototype

The subject's project is to develop a desktop robot to make a pipetting process automatic. Chemical or biochemical applications that dispense a selected amount of liquid into a designated container use this process. Manually performing this process is labor intensive and can be error-prone, wasting time, effort, and even samples. Automatically running this process is intended to increase efficiency eliminating the possibility of failures or errors, as well as free users up for other less labor-intensive tasks.

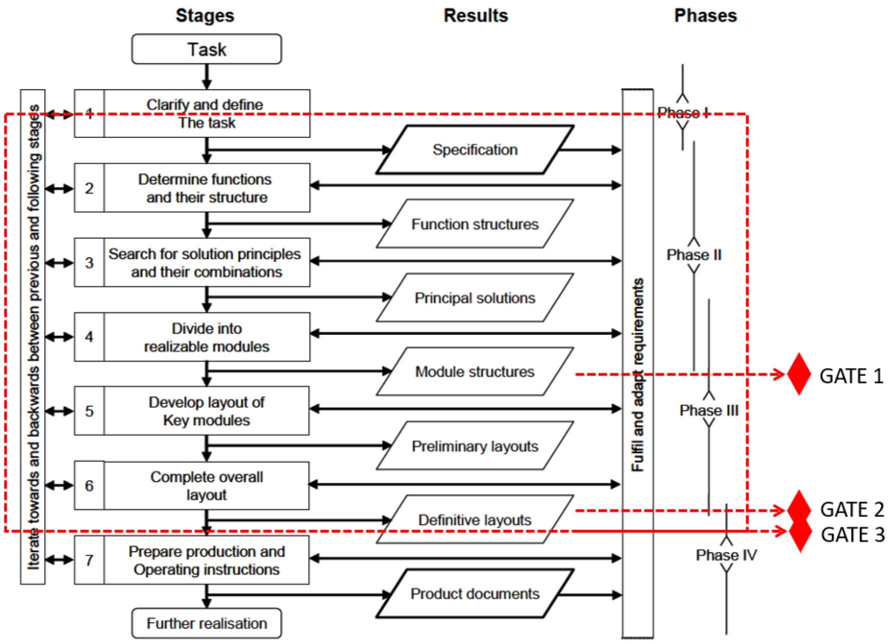

Figure 1. Guideline VDI 2221 apud Jänsch & Birkhofeand, 2006 (adapted).

As shown in Figure 2, students have access to some items while they need to design, manufacture, specify, and purchase others to develop the desktop robot. It is essential to integrate all these items to complete the robot successfully.

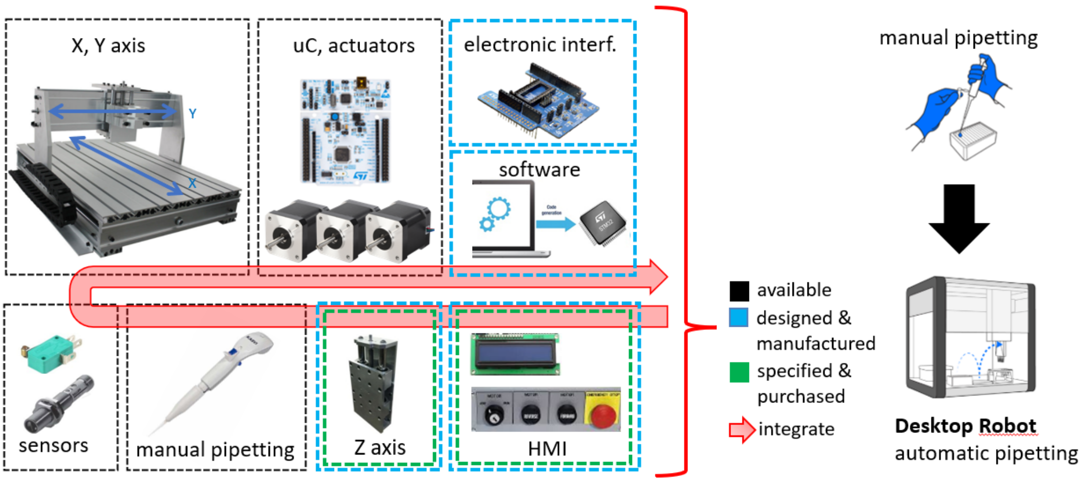

Figure 2. Proposed project for the mechatronic project course.

3 Mechatronic Project Course Dynamics

This section details the dynamics of the mechatronic project course and its integration with the other courses of the semester. It also describes assessment tools and rubrics used to measure student performance.

Classes have two distinct contents, theory, and application of PDP tools and studios, where technological content in mechanics, electronics, and programming areas apply.

In the first few weeks of the course, students define the workgroups, ideally composed of up to five students each. However, depending on the total number of students in the class, this number may occasionally vary between four and six students. It ensures a balanced workload for each member and facilitates the achievement of the project objectives, which include developing a conceptual project and creating a functional prototype.

The assessment of learning objectives is carried out through various methods, including partial project deliverables, tests, presentations, self-assessments, and peer assessments. These methods are applied throughout the course duration, providing individual feedback and monitoring the progress of each group's project. The course has two parts, each with a specific set of assessment tools. The evaluation tools and a brief explanation are presented next.

First half of the course:

- Delivery 1: Benchmarking, Requirements List and Key Technical Characteristics
- Delivery 2: Global Function, Block Diagram of Function Structure, Matrix, and Solution Variants
- Delivery 3: Schedule, Safety Requirements, and Risk Analysis
- Initial Test: Test about general content of mechatronic projects
- GATE 1: Conceptual Design. Presentation to an evaluation board composed of semester professors and guests, and delivery of the Conceptual Project documentation.
- Initial Self-assessment and peer assessment (Initial SA/PA)

Second half of the course:

- Delivery 4. Specifications and technical drawings of the mechanical elements and the entire assembly.
- Delivery 5: Power interface drive and routine programming for the motor positioning.
- Final Test: Test about specific content of the subject's project: PDP, mechanics, electronics, and programming.
- GATE 2: Preliminary Design. Presentation to an evaluation board composed of semester professors and guests, and delivery of the Preliminary Project documentation.
- Final Self-assessment and peer assessment (Final SA/PA)
- GATE 3: Physical Prototype. Prototype presentation and evaluation.

These assessments are individual (AI) and group (AG), with different percentage contributions for defining the final average:

60% of the final average (group evaluation): Delivery 1-5, GATE 1, GATE 2 e GATE 3

40% of the final average (individual evaluation): Initial SA/PA, Final SA/PA, Initial Test and Final Test

Examples of each stage of the PDP phases' deliveries will be presented next.

GATE 1 - Conceptual Design:

Students receive initial information such as the task to be performed by the desktop robot, initial technical conditions, and the user profile. Based on this information, the following are developed: (i) Benchmarking, (ii) Requirements List, (iii) Key Technical Characteristics, (iv) Global Function, (v) Function Structure Diagram Block,

(vi) Solution Matrix and Solution Matrix Reduction, (vii) Solution Variant selection and Solution Sketch, (viii) Schedule, (ix) Safety Requirements and (x) Risk Analysis.

Figure 3 shows an example of a Function Structure Diagram Block, which is essential for understanding the transformations between the inputs and outputs of material, energy, and signal.

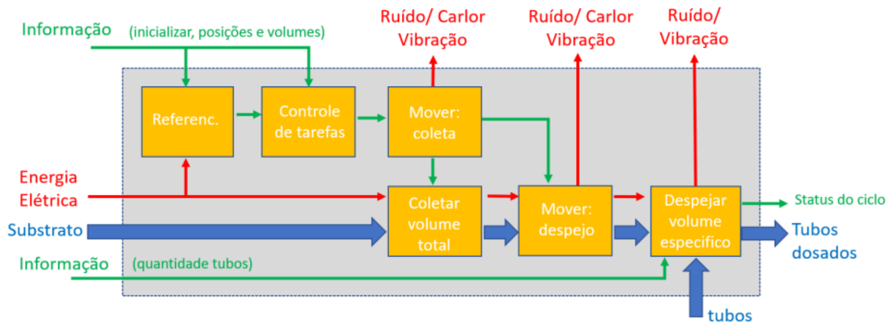

Figure 3. Function Structure Diagram Block

Figure 4 presents identified solutions for each transformation, along with their evaluations.

Figure 4. Solution Matrix and Solution Matrix Reduction

Figure 5 shows a selection of possible solution combinations (variants), along with a draft of the chosen variant.

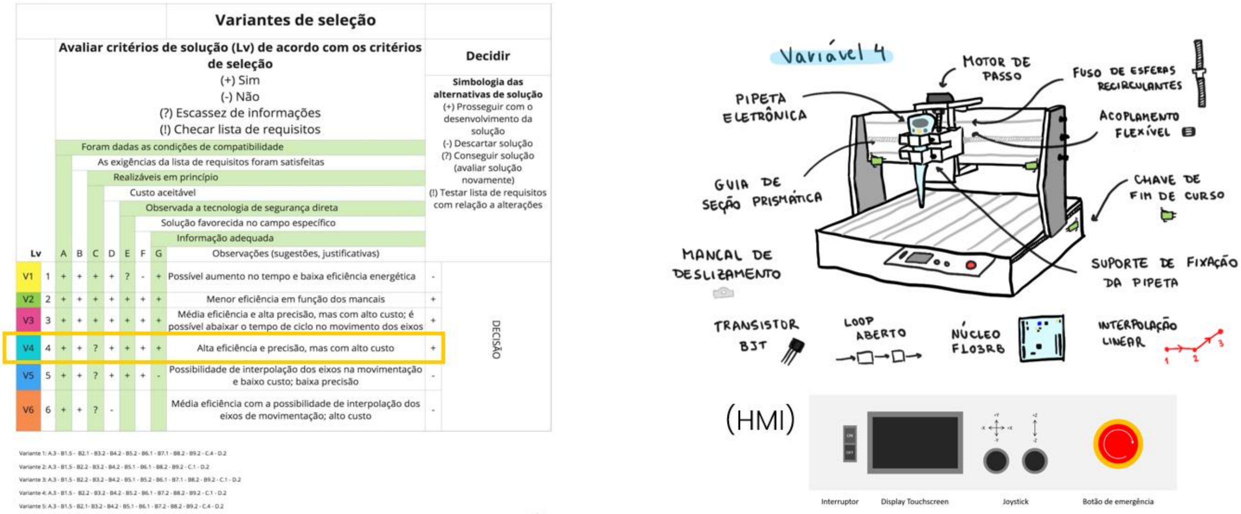

Figure 5. Solution Variant selection and Solution Sketch

<u>GATE 2</u> - Preliminary Design

After completing the Conceptual Design phase, students proceed to the Preliminary Design phase. In this phase, the following items are delivered: (i) Z axis Mechanical Design, (ii) Electronic Design of input and output interfaces, (iii) Microcontroller Algorithms and Programming Routines.

The figure 6 shows examples of design and fabrication stages of the Z-axis.

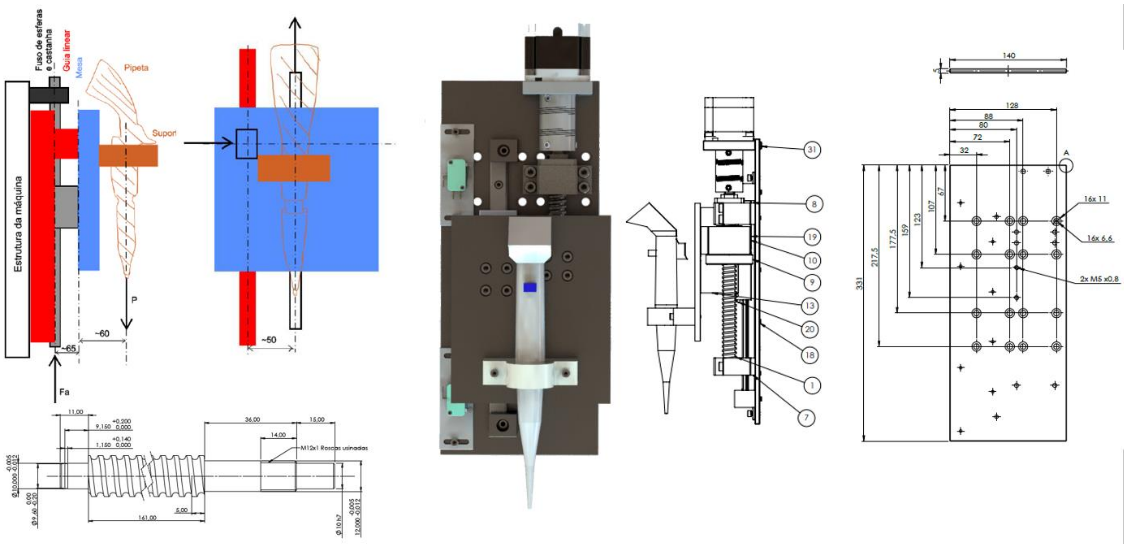

Figure 6. Specifications of mechanical elements, 3D Modeling and Mechanical Technical Drawing

Figure 7 shows examples of electronic interface design stages.

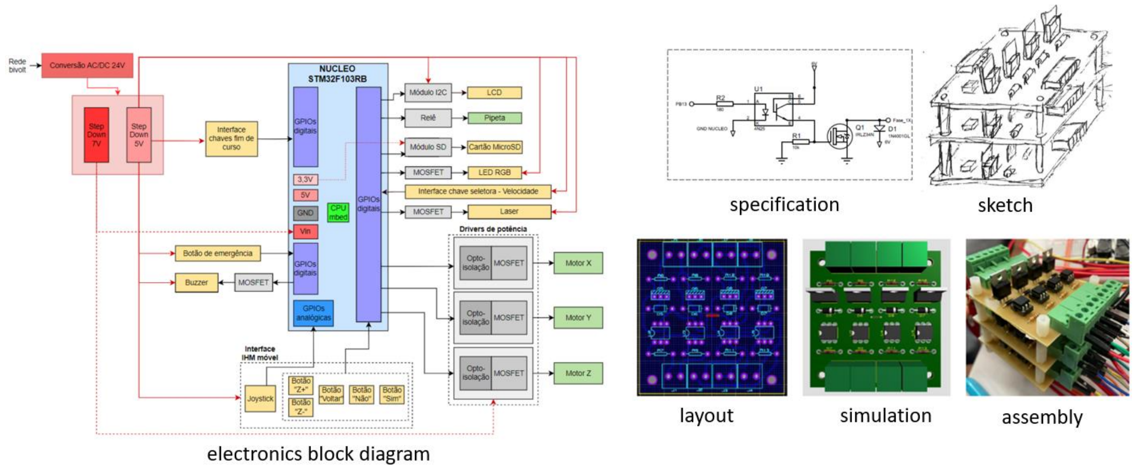

Figure 7. Block diagram of electronic elements and PCB board manufacturing process

Figure 8 presents examples of stages for programming microcontroller routines.

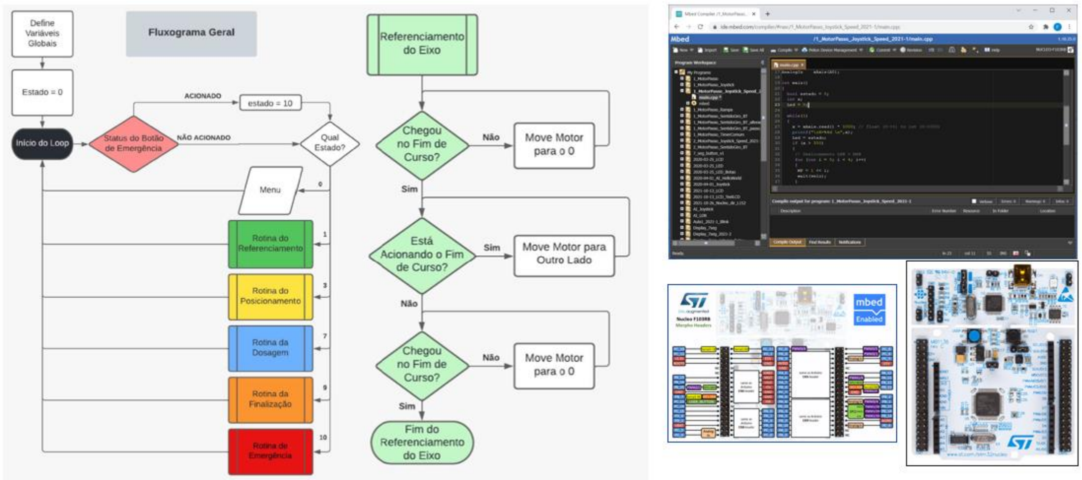

Figure 8. Algorithm flowcharts of the desktop robot routines

<u>GATE 3</u>: Physical Prototype. In this phase, the physical prototypes of the desktop robots are presented for evaluation. Figure 9 shows some examples. It is possible to identify the gantry system of the desktop robot, with the pipettes fixed on the manufactured Z axes and various HMIs.

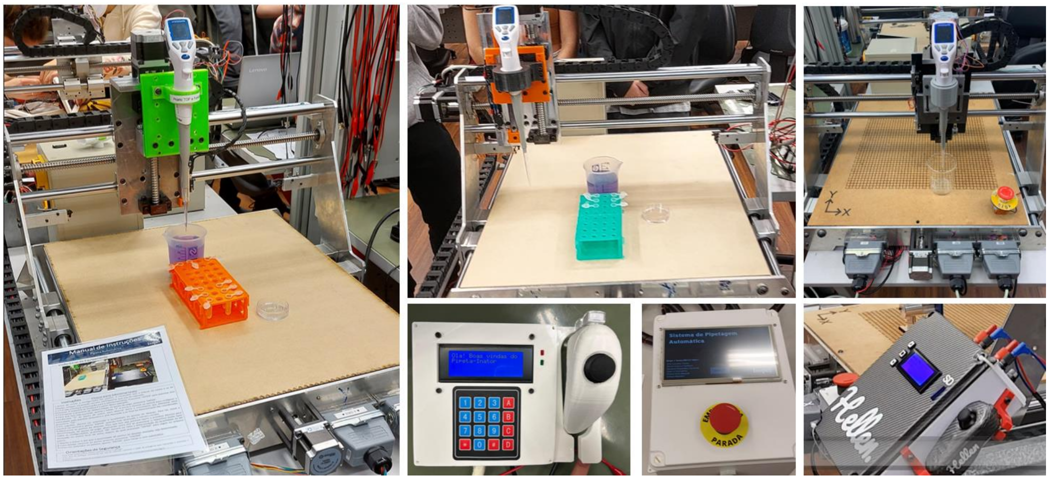

Figure 9. Physical prototypes examples

4 Learning Effectiveness Assessment

To evaluate the effectiveness of active learning strategies, a survey was conducted among undergraduate students at different stages of their academic journey, including those who had recently completed the course and those who were in the final stages of their capstone project. The survey questions were adopted with Likert scale responses ranging from totally disagree to totally agree. The results on the project-based teaching methodology are presented in the following graphs (Figure 10). The first result indicates that more than 70% of respondents completely agree that project-based learning has helped them understand how theoretical concepts are applied in practice, highlighting the practical benefits of this teaching method. The second result shows that almost 60% of respondents completely agree that the project-based teaching approach has increased their motivation to learn. Finally, the last result indicates that there is no disagreement regarding the effectiveness of the Mechatronic Project course in integrating the other courses of the semester.

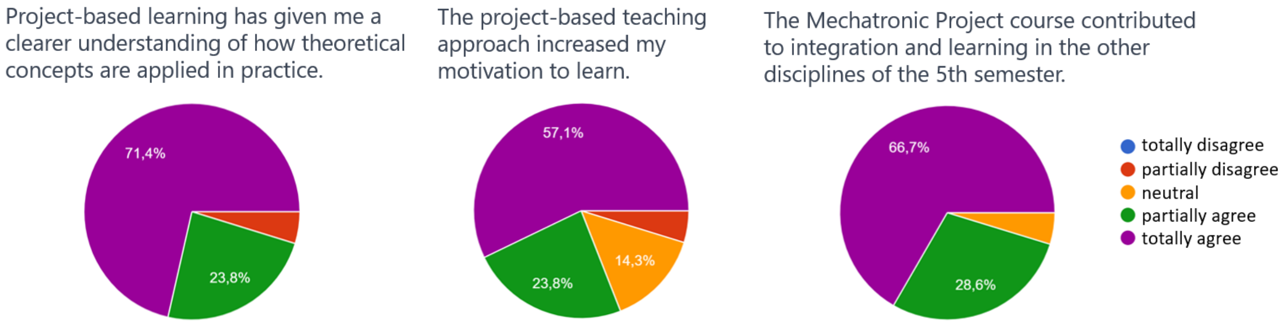

Figure 10. Results on project-based teaching methodology

The results of the achieved learning objectives, as perceived by the students, are presented in the following graphs (Figure 11). They indicate a positive perception among respondents regarding their capabilities achieved. The majority either completely or partially agree, highlighting their confidence in these areas. Overall, these findings confirm the effectiveness of the educational program in empowering participants with essential knowledge and skills in their respective fields. However, the small percentage of respondents expressing disagreement suggests areas where additional support or development may be needed.

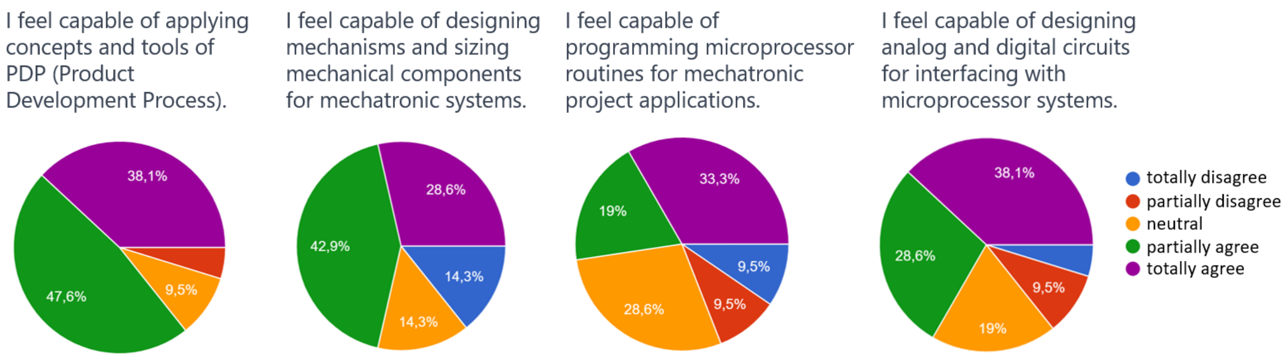

Figure 11. Results of Achieved Learning Objectives

5 Conclusions

This study presents a case of project-based learning applied in the mechatronic project course. It details the learning objectives of the course, its dynamics and integration with the other courses of the semester. It provides information about the use of assessment tools to measure student performance, as well as examples of results from the PDP stages and physical prototypes. Such information can be useful for educators interested in implementing project-based learning in their own courses. In conclusion, the positive results obtained in this study demonstrate the effectiveness of project-based learning in improving students' learning experiences within the context of a Mechatronic Project course. The findings suggest that project-based learning can enhance students' ability to apply theoretical knowledge to real-world situations and increase their motivation to learn. Furthermore, the Mechatronic Project course appears to have a positive impact on students' understanding and application of knowledge across multiple courses, which is crucial for success in the field of mechatronics. These results highlight the potential of project-based learning to enhance students' learning experiences and better prepare them for successful careers in engineering.

6 References

Casner, D., Renaud, J., Houssin, R., & Knittel, D. (2012). A novel design approach for mechatronic systems based on multidisciplinary design optimization. ICAM 2012: International Conference on Automation and Mechatronics, Aug 2012, Norway.

Copot, C., Ionescu, C., & Keyser, R. (2016). Interdisciplinary project-based learning at master level: control of robotic mechatronic systems. IFAC – Papers Online, Volume 49, Issue 6, pages 314-319.

VDI 2221 (1993). Systematic Approach to the Development and Design of Technical Systems and Products, Beuth Verlag.

Pahl, G., Beitz, W., Feldhusen, J., & Grote, K.-H. (2005). Projeto na Engenharia: fundamentos do desenvolvimento eficaz de produtos, métodos e aplicações. 6a edição, Ed. Edgard Blücher, São Paulo, 411p.

Jänsch, J., & Birkhofeand, H. (2006). The development of the guideline VDI 221 – The change of direction. International Design Conference - DESIGN 2006. Dubrovnik - Croatia, May 15 - 18.

Experiences in Team-based learning for Materials Engineering Program

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Abstract

Traditional engineering education practices are often criticized for their limitations, which include presenting a large amount of information to many students without fostering skill development or engagement during the learning process. In contrast, active learning methodologies such as Team Based Learning (TBL) encourage student engagement by placing them on teams that work together during class time to apply course concepts and solve discipline-relevant problems called application exercises. The present study describes an experience report from a professor who adopted TBL in the Materials Engineering Program at Fluminense Federal University. The study explored how TBL performance tests reflect in the resolution of application exercises, and found that both students and teachers had favorable perceptions of the method. TBL improved learning, enhanced integration and exchange of knowledge among students during class, and encouraged the adoption of the method among other teachers of engineering courses. Additionally, the study identified a pattern in the evaluation of students between the results of tests and the resolution of application exercises, showing that engaged students tend to perform better in the classroom, and that these students maintained their motivation throughout the learning process.

Keywords: Team Based Learning; Materials Engineering; Active Learning; student's engagement.

1 Introduction

Recently, the Ministry of Education (MEC) released the new National Curricular Guidelines for undergraduate Engineering courses through Resolution CNE/CES No. 2, of April 24, 2019, in Brazil. The changes aim to update the course curriculum, improve the training of future engineers, and meet the demands of the job market (Brasil, 2019)

In this context, it is essential for universities to employ innovative pedagogical resources that prioritize student engagement in the learning process, promote creativity and innovation, and develop both hard and soft skills. Among the various teaching strategies available, active learning methods stand out as particularly effective in achieving these goals. One example of an active learning technique is Team-Based Learning (TBL), which is a pedagogical strategy that promotes active learning and small group instruction. It offers students the chance to apply their conceptual knowledge through a series of activities that involve individual work, teamwork, and immediate feedback. (Maynard, Garcia, Lucietto, Hutzel,& Newell, 2021).

Team-Based Learning (TBL) is an educational approach that was developed in the 1970s by Larry Michaelsen that usually involves a series of steps:

(1) Individual Preclass Preparation: students are provided with a list of learning activities accompanied by a set of learning goals. Prior to the TBL session, students must have completed individual assignments to become familiar with subject concepts. The preparation materials encompass a variety of resources, such as readings, videos, labs, tutorials, lectures, and other materials.

(2) Individual readiness assurance test: Each student completes a set of multiple-choice questions, typically ranging from 10 to 20, that focus the key concepts necessary for successfully solving problems. Additionally, this test serves to assess their preparedness.

(3) Team readiness assurance test: students come together as a team to retake the same set of questions that they answered individually. This collaborative process encourages discussion and consensus-building among team members. Immediate feedback is crucial in this stage, as it helps the team assess the accuracy of their answers and refine their decision-making process. This test serves as a valuable opportunity for students to engage in collaborative problem-solving and enhance their overall understanding of the subject matter.

(5) Application exercises or problems: Students apply their learning to solve application exercises or problems. This is the most crucial step! In teams, students are presented with a scenario or vignette that resembles the types of problems they will encounter in their careers. They are challenged to make interpretations, calculations, predictions, analyses, and synthesize given information in order to make a specific choice from a range of options. They then post their choice when other teams do the same, and if asked, explain or defend their choice to the class.

(6) Peer-to-peer assessment: each student is required to evaluate their teammates based on their contributions to the team's success and their individual learning. It is beneficial to include both quantitative and qualitative components to encourage students to provide constructive feedback to one another. The evaluation process should be anonymous, but team members are encouraged to have direct communication when giving feedback. (Najdanovic-Visak, 2017; Oliveira, Lima,, Rodrigues & Pereira Júnior, 2018; Parmelee, Michaelsen, Cook & Hudes,, 2012).

The TBL offers numerous advantages, such as enhanced student participation and engagement in classes, improved retention and application of information, fostering teamwork and collaboration skills, promoting active and student-centered learning, enabling personalized learning to meet individual student needs, and facilitating the resolution of real-world problems and practical application of knowledge. While TBL has many advantages, there are also some disadvantages to consider, including the need for time and resources to prepare materials and activities, potential conflicts among team members, difficulty in individually assessing students' performance in group activities, possible discomfort of some students in actively participating in such activities, and the requirement for adequate physical space to accommodate larger groups (Oliveira, Lima,, Rodrigues & Pereira Júnior, 2018; Parmelee, Michaelsen, Cook & Hudes,, 2012).

It is important to remember that disadvantages can be minimized with careful preparation and planning on the part of the teacher, along with clear communication of expectations and goals. Furthermore, Team-Based Learning (TBL) can achieve results that are nearly impossible in a lecture-based course format. Taking into consideration that the benefits of TBL outweigh the disadvantages, this methodology was tested in the Materials Engineering Program at Fluminense Federal University.

The Materials Engineering Program under consideration was established in the second semester of 2018 and is taught in a region renowned for its thriving industrial and steel production sectors in the state of Rio de Janeiro. Some of the professors teaching fundamental and specialized courses, particularly in metallic materials, previously taught at the former School of Metallurgy at the National University of Labor, established in 1961. Despite their extensive professional experience in the industry, these professors may have limited familiarity with current didactic and learning methodologies (Universidade Federal Fluminense, 2018). The present study presents an experience report from a professor who implemented TBL in the Materials Engineering Program at Fluminense Federal University. The objective of this report is to demonstrate the feasibility of incorporating active learning methods, including TBL, in an engineering program where teachers have challenges or limitations in their didactic-pedagogical approaches.

2 Methodology

The team-based learning (TBL) in an adapted way was implemented in the Materials Engineering Program at Fluminense Federal University for students in these disciplines: Thermoplastic Processing (6 Module) and Processing of elastomers and thermosets (8 Module). A total of 15 students were involved in this research.

2.1 Application of adapted TBL Method

The traditional TBL method involves a sequence of steps that must be followed. However, in this study, the peer assessment step was not implemented, and the students attended an expository lecture about the content before beginning the TBL activities. It is important to note that the absence of peer assessment did not have a significant impact on the classmates' progress in the activity. This method was only applied once during the course, and the assessment may not necessarily reflect the student's overall behavior, but rather a specific situation. It is crucial to remember that assessments are a momentary measure of a student's performance and that various factors can influence the outcome, such as personal issues. Furthermore, as the students were not familiar with active learning, therefore the expository lecture provided a sense of safe haven. The TBL method was adapted to better suit the needs of the target audience.

Step 01 - Preparation: Prior to implementing the TBL Method, the teacher delivers an expository lecture, followed by distributing support materials to aid in familiarizing the students with key concepts. Individual study takes place before classroom sessions, with reading materials made available seven days prior to class meetings via Google Classroom

Step 02- Evaluation: All tests that had been assign to the student were completed during meeting in the class.

Individual Readiness Assurance Test (iRAT): the teacher gave the test for students to evaluate whether the student understood the main aspects of the material. The tests were composed by five multiple-choice tests that were related to the content presented as supported material. The students had 10 minutes to do it.

Teams: the students had been divided into small teams of 3 members.

Readiness Assurance Test as a team (tRAT): the students received the same test that they had done individually but now they must be resolved as teams. The students could interact with others to transfer knowledge between mattes and confirm the correct answer by immediate feedback by period of 30 minutes.

Step 03 -Application exercises (AE): in teams, in order to put course content in practice, the students must solve the application exercises. The application exercises have been assigned to the student during the class, but they have completed outside of class. In the next class, the students showed the results of the application exercises.

Using a combination of these assessment methods helped to provide a more comprehensive evaluation of the students' progress and readiness in the course, allowing for targeted interventions and support to help students succeed.

Team-based learning procedure throughout the classes was illustrated in Figure 1.

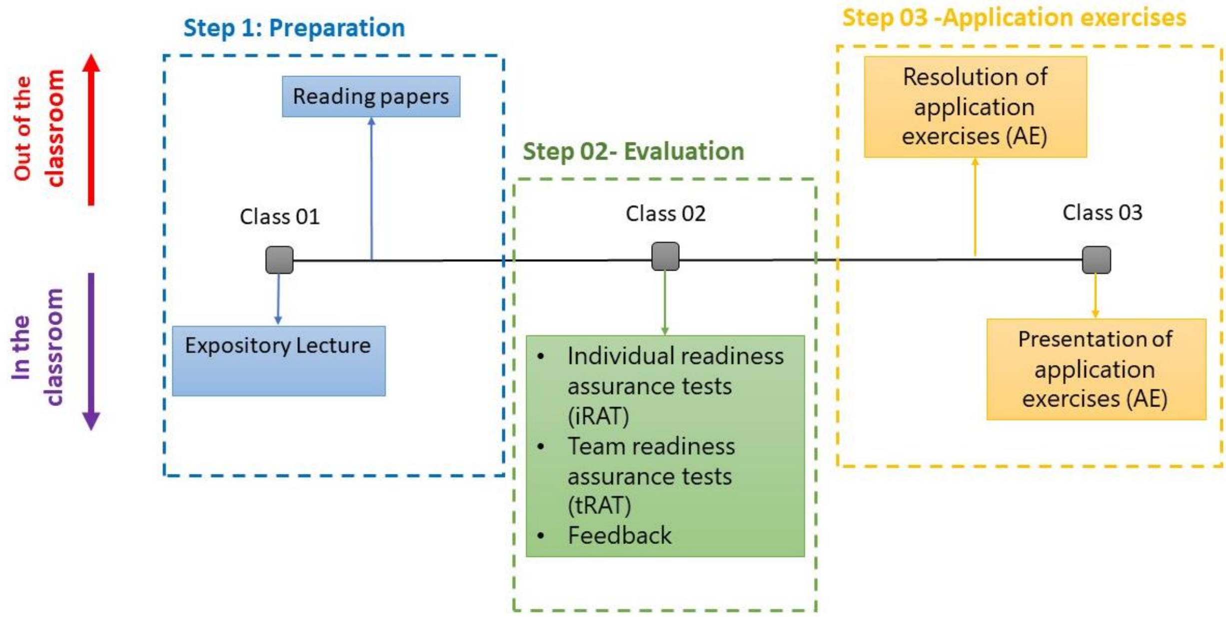

Figure 1. Team-based learning procedure throughout the classes.

To apply this teaching strategy, three classes were held with activities conducted both inside and outside the classroom as description in Figure 1.

2.2 Evaluation

The team-based learning (TBL) was used like a methodologies of evaluation learning of the students of Thermoplastic processing and Processing of elastomers and thermosets course. In this case, TBL accounts for 5% of the final course grade, as it constitutes one activity out of an average of 15 activities throughout the discipline. For activity individual readiness assurance tests (iRAT) represented 20%; team readiness assurance tests (tRAT) represented 30%; application exercises (AE) represented 50% to activity score.

The correction of the activities was done as follows:

1. Individual readiness assurance tests (iRAT) consisted of a 10-point test in which each correct answer was awarded 2 positive points.
2. Team readiness assurance tests (tRAT): similarly to the iRAT, the tRAT was also worth 10 points per test, but incorrect attempts were penalized with 0.5 negative points, while each correct answer was awarded 2 positive points.
3. Application exercises (AE): was valued at 10 points, and the quality of the work was assessed based on its coherence and justification. Work that correctly answered the question with a coherent justification was classified as Excellent (10 points), while work of low quality that lacked justification was classified as Insufficient (0-4 points).

3 Results and discussion

For the course of Thermoplastic processing and Processing of elastomers and thermosets, TBL was used as described in Figure 2.

Thermoplastic processing

Objective: *To ensure greater productivity in the manufacturing process of polymers, it is crucial for students to have knowledge of various screw designs used in polymer extrusion.*

STEP 1: Preparation:
Class: Extruder operation
Paper: "Conceitos Sobre Projetos de Roscas Para Extrusão"

STEP 2*: Individual Readiness Assurance Test and Readiness Assurance Test as a team:
An extruder built in the department is having a problem with plastification, what could be done:

A. Reduce extrusion temperature
B. Modify thread for multiple threads
C. Insert barrier fillets
D. Increase the fillet width

STEP 3: Application exercises
Define the screw geometries of this mini-extruder and estimate the productivity (m3/s) .

Processing of Elastomer and Thermosseting

Objective: *In order to propose process conditions that enhance the mechanical properties and productivity, students must have a thorough understanding of the cure kinetics of thermosetting resins.*

STEP 1: Preparation:
Class: Curing of thermoset polymers –Polymerization
Paper: "Métodos de Estudo da Cinética de Cura de Resinas Epóxi"

STEP 2*: Individual Readiness Assurance Test and Readiness Assurance Test as a team:
Regarding the curing of thermosetting resins, we can say that:

A. The curing reaction needs a resin and an initiator to start.
B. B. Curing is a reaction that promotes compatibility between the starting reagents.
C. Curing is an irreversible chemical reaction defined by chemical and physical changes.
D. Curing mechanisms can only be related when the resin is used alone

STEP 3: Application exercises
Assemble a work plan in order to determined the curing parameters for a new epoxy resin

Figure 2. Description of TBL was used during Thermoplastic Processing course and Processing of Elastomers and Thermosets course. (STEP 2*: this question is one of 10 questions in this step and serves as an example.)

Before beginning to use TBL, the class objectives were presented to the students which were designed to equip them with knowledge necessary for their future professions. As an illustrative example, in Thermoplastic Processing, students must possess a comprehensive understanding of equipment operations to attain high levels productivity of an extruder.

The selection of papers for this activity was based on several criteria, including: (1) language, as the use of English could pose a challenge for some students, Portuguese papers were selected; (2) didactic quality of the material, with a preference given to papers that have content relevant to the subject matter, such as review papers or those with introductions that explain the class topics; and (3) publication date, as the previously mentioned criteria were deemed essential in the selection of papers, those used in the TBL activity were published over than 20 years ago. These measures were taken to ensure that the selected papers were not only accessible to all students but also provided them with the necessary information and knowledge required to complete the activity successfully.

The Individual Readiness Assurance Test (iRAT) and Team Readiness Assurance Test (tRAT) were based on the selected papers. As a result, it was observed that the students began to engage more deeply with the didactic texts. In formulating the tests, questions were designed to not only assess the students' memorization of the subject matter but also their ability to understand and apply the acquired knowledge. To achieve this, the questions were formulated in a way that provides a meaningful context to the knowledge being tested. During Team Readiness Assurance Test, it was observed that the internal discussions within the teams were particularly lively. Due to the immediate feedback provided, the teams displayed increasing levels of enthusiasm as they answered questions correctly. In instances where their answers were incorrect, they engaged in in-depth discussions to understand the reasoning behind the correct answers. This approach fostered a deeper level of engagement and understanding among the students.

The final step in this process involved the application of the knowledge gained by the students in real-life situations. For instance, in the Processing of Elastomers and Thermosets course, students were required to predict the appropriate procedure to be followed if their company received a new resin for use in the production of a fiberglass composite, but the curing parameters for the resin were not specified. To achieve this, they had to develop a work plan that included the following items: (a) the necessary equipment for conducting a kinetic study; (b) the conditions for carrying out the tests; (c) a flowchart outlining the study to be conducted; and (d) expected outcomes at the end of the study.

The proposed problem is highly relevant for future materials engineers, as they are expected to be high-level professionals with a solid technical background in materials processing, development, and selection. They should also possess a humanistic perspective and the ability to identify and solve problems of professional and social significance. The solution for proposed problem is not simple and involves a series of choices, both in terms of equipment and testing conditions. To find a solution, students primarily worked on their decision-making skills through team discussions. On the day of the activity submission, a debate was held among the groups to determine the best approach to solve the problem. During this debate, students had the opportunity to defend their viewpoints and listen to suggestions and considerations from other groups. By the end of the activity, students who actively participated and demonstrated active listening skills became more technically and behaviorally competent in handling unprecedented situations, as they were exposed to different perspectives and shared ideas during the discussion process.

The use of TBL in this manner can encompass the first three levels of Bloom's Taxonomy: the first level, remembering, which entails recalling or recognizing information; the second level, understanding, which involves comprehending information and being able to explain it in one's own words; and the third level, applying, which involves using information in a new situation or context (Ferraz & Belhot, 2010). Therefore, the activities were designed to help students apply their knowledge in practical and meaningful ways, thereby preparing them for future career opportunities.

To assess the effectiveness of TBL for students of Materials Engineering, a performance analysis was conducted and the results are presented in Table 1.

Table 1. Average scores of iRTA, tRAT and AE.

Course	**Year/ semester**	**Average Scores (%)**			
		iRAT*	**tRAT***	**AE***	**Final**
Thermoplastic processing	2022/1	53,33	90,00	90,00	82,67
	2022/2	60,00	80,00	96,67	84,34
Processing of elastomers and thermosets	2022/1	52,50	81,67	90,00	80,00
	2022/2	60,00	85,00	86,00	80,50

* iRAT: Individual readiness assurance tests (iRAT); tRAT: Team readiness assurance tests (tRAT); AE: Application exercises.

Table 1 shows tests and exercises of grade averages for each of the course, administered in both semesters of 2022. Results from the individual readiness assurance tests indicated that students did not have a comprehensive understanding of the material, as their scores were near the minimum passing. However, engagement in team-based learning activities led to significant growth and development among students, resulting in final scores that were sufficient for course approval if these activities were the only method of evaluation used. It has been observed that group performance (tRAT and AE) is superior to individual (iRAT) performance, with average grades for group responses being around 30% higher, thus suggesting team interactions are effective independently of course.

The strong performance in group activities can primarily be attributed to two factors: increased engagement resulting from collaborative work and the additional time devoted to studying the subject matter. There is a clear and notable improvement in performance between the Individual Readiness Assurance Tests (iRAT) and the Team Readiness Assurance Tests (tRAT). This improvement in performance can be credited to the efficacy of Team-Based Learning (TBL) in fostering student engagement through active participation and immediate feedback (Sharma, Janke, Larson & Peter,2017). However, it is important to note that the advancement in learning cannot be attributed to prolonged exposure to the content, as there was insufficient time between the tests for substantial knowledge acquisition. On the other hand, during the execution of application exercises, students were provided with a week to reflect, research, and analyze the given problem. It is evident that engagement alone was not the exclusive determinant of performance in this case. The additional time allocated to the activity may have played a role in improving the scores in this specific aspect of TBL. Therefore, it is plausible that both increased engagement in group activities and additional time dedicated to studying have contributed to the observed improvement in students' scores.

As mentioned above, the ability to work in a team has been identified as one of the most important attributes that students are expected to develop during their undergraduate engineering degree course. According to the teacher's perceptions, the implementation of TBL has proven to be an effective method for honing good interpersonal communication skills and gaining experience in dealing with conflicting views, as seen in previous studies (Choi, Slaubaugh & Tian, 2021). In summary, TBL is a valuable tool for developing the teamwork skills necessary for success in the field of engineering.

As evidenced by the previous results, Team-Based Learning (TBL) has been shown to improve teamwork skills among students. However, the level of success achieved through the learning process largely on the level of student engagement. In this study, five students were randomly selected per course and their initial engagement, as well as its continuity, was evaluated by comparing their individual test and application exercises results (Figure 2).

In Figure 2 observed that the students consistently demonstrated an improvement in their grades as they progressed through the presented activities. Therefore, considering that students who are engaged in activities tend to perform better in the classroom, the analysis of grade evolution across sequential activities (iRAT>tRAT>AE) indicates that these students maintained their motivation throughout all learning process.

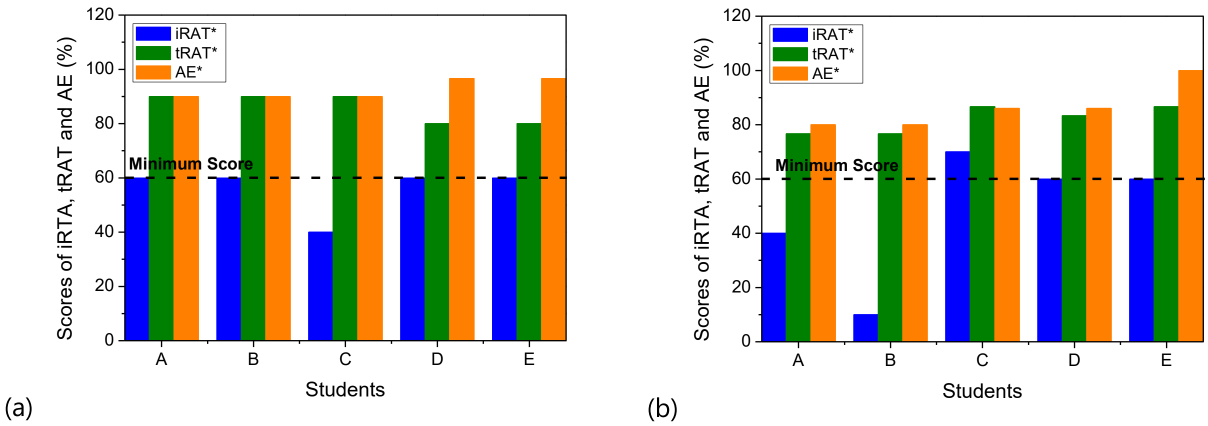

Figure 2. Scores of iRTA, tRAT and AE for random students of course: (a) Thermoplastic processing; (b) Processing of elastomers and thermosets.

The results indicate that a majority of students scored below or at the minimum expected level, indicating that students had an inadequate preparation and they still have uncertainty about the provided material. The Individual Readiness Assurance Test (iRAT) plays a crucial role in the learning process, ensuring that all team members were prepared for the Team-Based Learning (TBL) sessions and engaged in focused discussions on the content. Despite inadequate individual preparation, the team Readiness Assurance Test (tRAT) results demonstrated that active participation and collaborative discussion were not significantly impacted.

Taking student B class of Processing of elastomers and thermosets as an example, we can observe an improvement in their performance throughout the TBL. Initially, the student B showed a significantly lower performance in the individual test compared to the other students. This difference in performance may indicate that student B encountered difficulties in understanding the content or applying the concepts. However, it is important to highlight that there was a substantial improvement in their performance in groups activities. This suggests that student B had the opportunity to clarify doubts, gain new perspectives, and develop a deeper understanding of the topic during interaction with other students. This progress highlights the importance of creating a collaborative learning environment where students feel comfortable discussing and sharing knowledge. Additionally, this experience provided student B with the opportunity to reflect on their study strategies and seek more effective approaches to enhance their individual performance.

The traditional teaching model has obvious limitations, and there is a need for an innovative approach to exercise students' abilities in multiple aspects, particularly in social interaction. Additionally, since Team-Based Learning (TBL) does not require a high investment, its impact on universities is minimal, making it a teaching methodology that can be easily incorporated into the course curriculum (Parmelee, Michaelsen, Cook & Hudes,, 2012).

4 Conclusion

The results of Team-Based Learning (TBL) for the students in the Thermoplastic Processing and Processing of Elastomers and Thermosets courses of the Materials Engineering Program at Fluminense Federal University indicate that this methodology should be continued. The students demonstrated an improvement in their grades as they progressed through the activities, which suggests that they maintained their motivation throughout the learning process. Although this study was limited to only two courses, the author expects that this experience with TBL in the Materials Engineering Program will facilitate and motivate the adoption of this methodology among teachers of engineering courses.

5 References

Brasil (2019). Resolução CNE/CES 2/2019 – Institui Diretrizes Curriculares Nacionais do Curso de Graduação em Engenharia. MEC: Brasília – DF.

Choi, S., Slaubaugh, M., & Tian, X. (2021). Integrating learning interpersonal skills through team-based learning (Tbl) in a management course. Journal of Education for Business, 96(8), 498–509.

Ferraz, A. P. D. C. M., & Belhot, R. V. (2010). Taxonomia de Bloom: Revisão teórica e apresentação das adequações do instrumento para definição de objetivos instrucionais. Gestão & Produção, 17(2), 421–431.

Maynard, C., Garcia, J., Lucietto, A., Hutzel, W., & Newell, B. A. (2021). Experiential learning in the energy based classroom. International Journal of Engineering Pedagogy (iJEP), 11(6), 4–26.

Najdanovic-Visak, V. (2017). Team-based learning for first year engineering students. Education for Chemical Engineers, 18, 26–34.

Oliveira, B. L. C. A. D., Lima, S. F., Rodrigues, L. D. S., & Pereira Júnior, G. A. (2018). Team-based learning como forma de aprendizagem colaborativa e sala de aula invertida com centralidade nos estudantes no processo ensino-aprendizagem. Revista Brasileira de Educação Médica, 42(4), 86–95.

Parmelee, D., Michaelsen, L. K., Cook, S., & Hudes, P. D. (2012). Team-based learning: A practical guide: AMEE Guide No. 65. Medical Teacher, 34(5), e275–e287.

Sharma, A., Janke, K. K., Larson, A., & Peter, W. St. (2017). Understanding the early effects of team-based learning on student accountability and engagement using a three session TBL pilot. Currents in Pharmacy Teaching and Learning, 9(5), 802–807.

Universidade Federal Fluminense (2018). Projeto pedagógico do curso de Engenharia de Materiais. Volta Redonda, Rio de Janeiro, Brasil.

Experience in Project-Based Learning (PBL) applied to remote and face-to-face classes in the Materials Engineering Program at a Brazilian university

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Abstract

Project-Based Learning (PBL) has gained widespread adoption in engineering education in recent years, offering numerous benefits to students' academic performance, including enhanced scientific knowledge, logical reasoning, teamwork, and communication skills. In Brazil, the use of PBL methodology in engineering education has seen significant growth over the past decade. With the emergence of COVID-19 in 2020 and 2021, teaching methods had to be adapted to remote delivery. This article presents the experience of implementing PBL in a remote classroom within the Materials Engineering Program at a Brazilian university. The project involved assigning students in the Thermomechanical Properties of Ceramic Materials course to design a fictional company website specializing in ceramic materials thermomechanical characterization. The evaluation of students' learning outcomes encompassed team project reports, team oral presentations, individual reports, and external assessments conducted by professors and practicing engineers in the Materials Engineering field, who acted as simulated customers with an interest in the services offered by the fictional company. Additionally, a survey was conducted to gauge students' perception of the applied methodology. Following the successful outcomes achieved through remote learning, the same activity was implemented in a face-to-face class after the resumption of in-person instruction. The results were highly positive, as students demonstrated a solid grasp of the theoretical knowledge. This methodology was implemented across three classes between 2021 and 2022.

Keywords: Project-Based Learning; Materials Engineering; Remote class.

1 Introduction

In the twentieth century, engineering education underwent significant transformations in response to market demands, emphasizing the acquisition of technical knowledge, skills, and competencies in management and communication (Rompelman,2000; Wankat & Oreovicz, 1993; Brito, 2018). Today, engineering professors face the challenge of preparing students for jobs and technologies that have yet to emerge, as the technology taught at the beginning of a degree program may become obsolete by the end. Consequently, future engineers will assume the responsibility of tackling unprecedented problems. Moreover, the persistently high dropout rates in engineering programs highlight the urgent need to reevaluate educational systems (Elmôr Filho, Sauer, Almeida& Villas-Boas, 2019).

In response to emerging demands, the National Curriculum Guidelines (DCN) for engineering programs were revised under Resolution No. 2 dated April 24, 2019. This resolution emphasizes the importance of implementing active learning methodologies and student-centered teaching approaches (MEC, 2019). Among these methodologies, project-based learning (PBL) stands out as an effective approach that promotes the integration of technical knowledge with essential skills that are not commonly developed through traditional academic training. These skills include leadership, project management, teamwork, and communication. In the field of engineering, PBL enables students to analyze problems within cultural and social contexts, fostering adaptability and problem-solving abilities that are vital in both academic and professional settings.

One of the notable advantages of this approach is its ability to foster self-directed learning, encourage open-mindedness towards diverse perspectives, and promote active and responsible engagement in the learning process (Tiwari& BansaL, 2017). The project-based nature of this approach stimulates greater student involvement, resulting in more effective acquisition of technical knowledge compared to traditional teaching methods.

During the years 2020 and 2021, the outbreak and rapid spread of COVID-19 necessitated a shift to distance learning. In this context, an activity was designed to be implemented throughout the second half of 2021, with the dual purpose of fostering closer interaction between teachers and students and facilitating continued learning despite the unavailability of physical spaces on campus. Furthermore, the necessary implementation of social distancing measures due to the pandemic posed challenges to engineering programs that heavily rely on laboratory activities. This paper aims to present the experiences of applying project-based learning (PBL) in the Materials Engineering course at EEIMVR-UFF, both in remote and face-to-face teaching environments.

2 Method

2.1 Context and participants

This report describes the experience of implementing Project-Based Learning (PBL) in the curricular component "Thermomechanical Properties of Ceramic Materials." The course is offered to 8th-semester students in the Materials Engineering program at the School of Engineering in Volta Redonda, UFF. The course aims to provide students with a comprehensive understanding of the fundamental concepts related to ceramic materials' properties and their correlation with thermo-mechanical performance. It also focuses on developing students' ability to evaluate parameters that influence mechanical behavior and comprehend the application of technological tests. To bridge the gap between theory and practice, the project involves the establishment of a fictional company and customer service, where students can apply theoretical concepts. Additionally, the course aims to develop skills such as effective communication (written, oral, and graphic), knowledge and application of standards and legislation, and the ability to assess the impacts of engineering activities in social, legal, economic, and environmental contexts. Therefore, the adoption of the PBL methodological approach is expected to align well with the objectives of this curricular component.

2.2 Description of the experience

The project involved the creation of a website for a company offering services in the thermomechanical characterization of ceramic materials. This approach aimed to not only assess students' understanding of the course content but also foster the development of additional skills in a challenging environment. The activity's developmental stages are outlined below:

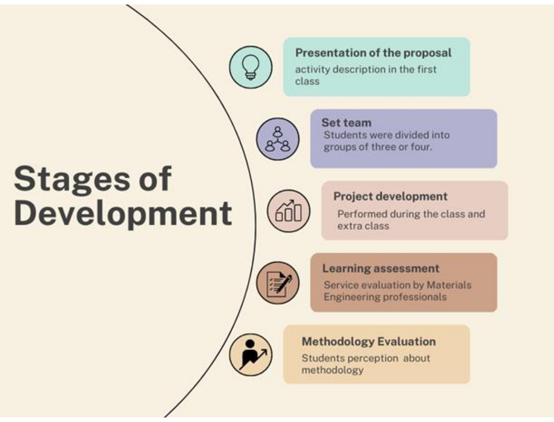


Figure 1. Image of the stages of project development.

The activity was introduced on the first day of class. Students were assigned to groups of three or four for each company. Throughout the course, both in virtual and face-to-face classrooms, various active methodologies were employed to study the different course topics. This approach motivated students to incorporate additional services into their company's website, fostering a deeper understanding of the content. The progress of website creation was monitored through regular reports, as depicted in Figure 2.

WEEK 1
COMPANY:
Completed Activities
Describe the activities carried out during the week and the contribution of each member of the team in carrying out the activities. If it was not possible to complete the activity, point out the reason.
Challenges
Describe the main difficulties encountered or the greatest challenges. Describe how it was resolved. If not resolved, describe what the team intends to do to solve it
Forecast for next week
Describe what you intend to accomplish in the next week. Assign the role of each member of the team.
Theoretical Reference
Sources consulted books, links, video and other types of information.

Figure 2. Weekly monitoring report.

Additionally, a team assessment and a self-assessment were conducted each week, as illustrated in Figures 3(a) and 3(b).

Self-evaluation	
Regarding your performance on the project, on a scale of 1 to 5, with 5 being very satisfied and 1 being very dissatisfied.	
1	Helped create a respectful environment
2	I was able to express my opinions
3	I was responsible for some task
4	I did what was agreed
5	I turned in my assignment on time
6	I was interested in developing the project

(a)

Project team evaluation	
Regarding the performance of the team regarding the project, on a scale of 1 to 5, with 5 being very satisfied and 1 being very dissatisfied.	
1	We managed to create an environment of respect
2	There was good communication in the team
3	Everyone was responsible for some task
4	Everyone did as agreed
5	Everyone delivered the assignments on time.
6	Everyone was interested in the project

(b)

Figure 3. Self-assessment of performance on the project (a) and evaluation of the team's performance on the project (b).

2.3 Evaluation

The project development constituted 40% of the final course grade, while the remaining 60% was allocated to a summative assessment designed to evaluate students' mastery of the subject. It is worth noting that the project grade pertained to the group activity, whereas the summative assessment grade reflected the individual evaluation of each student, with a greater emphasis placed on the individual assessment. The summative assessment primarily comprised theoretical knowledge-based questions; however, in the 2022 class, an additional question that required the application of concepts in a practical example was incorporated.

The evaluation of the project by the instructor encompassed the development of competencies such as effective oral and written communication, teamwork skills, and project management. These aspects were assessed through the monitoring of weekly reports, team evaluation, self-assessment, participation in classroom activities, and a final oral presentation on the project's development. The evaluation of theoretical concepts focused on the ability to identify the appropriate tests for each type of ceramic material, considering their characteristics and compliance with relevant standards. This evaluation was based on the information available on the project page and the arguments presented during the project's presentation.

The evaluation conducted by experts involved verifying the accuracy, clarity, and completeness of the information provided in the description of the tests on the website. Additionally, the students' capacity to relate theoretical content to practical application was assessed through their recommendations of thermomechanical tests that adequately met the specific requirements set by each evaluator and effectively addressed their inquiries. The main evaluation criteria used by the external assessors are presented in Figure 4 (a).

.

Project- Ceramic thermo-mechanical characterization company	
Evaluate the companies on a scale of 1 to 10, considering 10 excellent.	
1	Did you like the website's graphics, design, and ease of navigation?
2	Was the information about the service passed on clearly and correctly?
3	Were the professionals able to understand your doubts properly?
4	Was the service time adequate?

(a)

Project- Ceramic thermo-mechanical characterization company	
Answer about the use of PBL in the course of Thermomechanical Properties of Ceramic Materials, on a scale of 1 to 5, with 5 being I totally agree and 1 being totally disagreeing.	
1	Can the content covered in the classroom be related to the project?
2	Will the skills developed in carrying out the project contribute to your academic training?
3	Did you receive the necessary instructions to carry out the activity?
4	The estimated time for completion of the project was sufficient?
5	Do you think you will be able to apply the knowledge acquired during the course in your professional practice?
6	Are the learning assessment instruments used to evaluate the project in line with what is proposed in the activity?

(b)

Figure 4. Assessment carried out by engineering professionals (a) and Students' perceptions about the methodology applied.

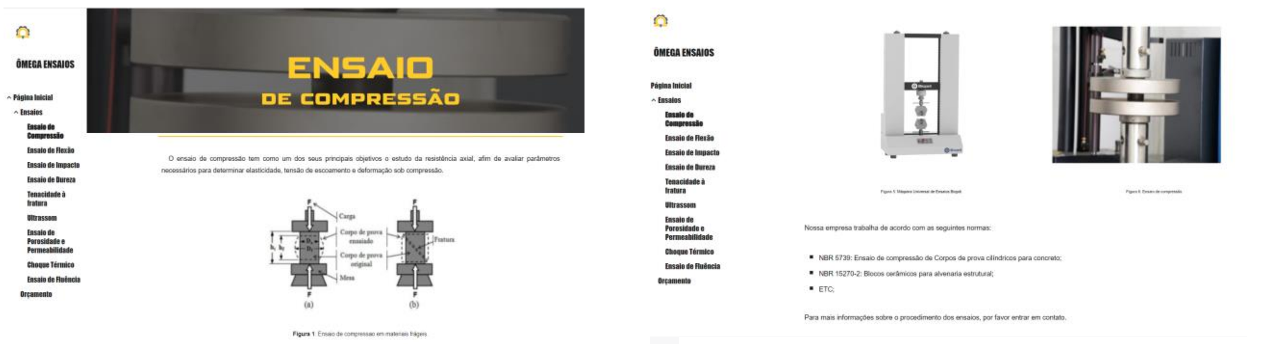
Furthermore, the students conducted team evaluations and weekly self-assessments, guided by the criteria outlined in Figure 3. These evaluations aimed to reflect on the team's progress in relation to the activity's objectives and each individual's contribution to its completion. The same method was employed for both remote and in face to face classes.

3 Result and discussion

At the end of the semester, the students presented their websites. They also engaged in discussions regarding the entire project development, including the main challenges faced, the individual contributions of each team member, and their perceptions of the learning acquired throughout the process. Figure 5 displays some examples of the final website products.

Figure 5. Examples of websites created by students.

Figure 6 presents the features of the website that are related to learning. On the left side of Figure (a), the list of available experiments is displayed, and in the center, the description of the selected experiment is shown. Figure 6 (b) depicts the equipment used in this experiment and the standards employed for its execution. The learning objectives of the course include understanding the utilization of technological experiments and specific technical standards employed in each experiment. The correct and clear presentation of information was a criterion used for evaluation and demonstrated that the activity fulfilled the learning objectives of the course.



(a) (b)

Figure 6: Examples details of websites created by students.

During the monitoring of weekly reports, a well-organized distribution of tasks within the groups was observed. Upon comparing the planned and completed activities, it was found that, in most cases, the students were able to successfully accomplish the planned tasks. In instances where tasks could not be completed, students provided explanations for the non-compliance and reflected on potential solutions to overcome the encountered difficulties. These findings indicate a satisfactory development of competencies such as project management and creative problem-solving.

Both group evaluation and self-assessment were employed to identify any aspects that did not meet the expectations of both the group and individual members. It was observed that when the team perceived a lack of regular contribution from certain members, this observation was also reflected in their self-assessment, where students acknowledged their below-desired level of participation. Therefore, self-assessment can be seen as a tool that promotes self-reflection and fosters accountability for learning outcomes.

Table 1 displays the grades assigned by the instructor for the summative assessment, the grades provided to the project by external evaluators and the instructor, as well as the final course average, taking into account both remote and in-person teaching.

Table 1. Grades for Summative Assessment, External Evaluators' and Instructor's Project Grades, Final Course Average (Percentage of Achievement) for Remote and In-person Teaching.

	Summative Assessment Grade (%)	Project Grade (Instructor) (%)	Project Grade (External Evaluators)(%)	Course Grade (%)
Remote	79,0	80,0	85,0	80,4
In-person	60,0	80,0	76,0	67,2

The evaluation of oral and written communication skills was conducted through student project presentations. The assimilation of content was assessed based on the information provided on the website and the arguments presented during the presentations. The instructor assigned a project grade of 80% for both remote and in-person teaching, reflecting the overall performance of the students. The development of teamwork and project management skills was deemed satisfactory based on regular monitoring throughout the project. Furthermore, students demonstrated satisfactory oral and written communication skills, as well as a solid understanding of the theoretical knowledge covered in the course.

The results indicated that students exhibited mastery of the theoretical content, with a performance above 70% for the remote teaching group and above 60% for the in-person teaching group. The slight difference in performance between the two groups may be attributed to the students' adaptation to the transition from remote to in-person teaching after an extended period of remote learning. In the in-person group, additional questions requiring practical application of the concepts were included, and a higher performance was observed in these items, all students rigth this questions suggesting that the project development contributed to linking technical knowledge with application.

According to student feedback collected through a survey, the applied methodology encouraged them to delve deeper into each topic presented. They identified creativity, entrepreneurship, communication, and oral and written expression as the main skills developed throughout the activity. However, some students mentioned the challenge of lacking prior knowledge in website creation. Here are a few comments from students regarding their perception of learning, as gathered from the survey and in response to the question: "What skills did you develop while completing this activity?"

> We analyzed the tests advertised on the website several times so that we could describe them succinctly; this required understanding the results that would be obtained and how the test would be performed. When necessary, we look for theories, norms, and companies that practice these tests. (Student 1)
>
> Team project and deadline management; understanding each type of thermomechanical test seen in the classroom; and understanding of the procedure applied to various tests. (Student 2)
>
> Entrepreneurship and skills related to layout development. (Student 3)

The evaluation by experts regarding the technical information on the website and the students' selection of tests was also considered satisfactory, both in in-person and remote teaching. The students demonstrated the ability to relate theoretical content to practice. The final grade of the course was determined by the average of the project grades, accounting for 40%, and the individual performance grade obtained through the summative assessment, accounting for 60%. As stated, although remote teaching showed higher performance in both cases, the students obtained a sufficient grade to pass the course.

The satisfactory results obtained from the implementation of TBL in remote teaching encouraged the application of the same methodology with the possibility of transitioning to in-person instruction. During the pandemic, students were isolated and performed all tasks using computer resources. A new context emerged when students returned to the university for in-person classes. However, the presented results indicate that satisfactory outcomes were achieved, considering the course was conducted both remotely and in-person. The students' perceptions were very similar, indicating the success and applicability of this active methodology in both in-person and distance education, contributing satisfactorily to the education of Materials Engineers at UFF.

4 Conclusion

Based on the results and discussion, it can be concluded that the active methodology tool used in the teaching of Materials Engineering, specifically in the course of Thermomechanical Properties of Ceramic Materials, demonstrated positive contributions in both remote and in-person learning. The students not only gained a solid understanding of technical knowledge but also demonstrated their ability to apply this knowledge in practice. The completion of the project played a significant role in developing competencies expected from engineering graduates, including the ability to recognize user needs, analyze problems, and creatively solve them. Additionally, the evaluation of student feedback indicated that the applied methodology encouraged a deeper understanding of the topics presented. Students identified creativity, entrepreneurship, communication, and oral and written expression as the main skills developed throughout the activity. Overall, the findings support the applicability and effectiveness of the active methodology in the teaching of Materials Engineering, contributing to the holistic development of students' competencies and preparing them for future engineering careers.

5 References

Brasil.(2019) Ministério da Educação.Diretrizes Curriculares Nacionais para os Cursos de Engenharia. Resolução CNE/CESnº 2, de 24 de abril de 2019 - Institui as Diretrizes Curriculares Nacionais do Curso de Graduação em Engenharia. 2019. Disponível em: http://portal.mec.gov.br/docman/abril-2019-pdf/112681-rces002-19/file. Acessed: March 10, 2023.

Brito, A. P. D. A (2018) Pesquisa aplicada e a inovação tecnológica na educação profissional: desdobramentos no Instituto Federal de Educação, Ciência e Tecnologia. Dissertação (Mestrado Profissional em Gestão e Desenvolvimento da Educação Profissional) – Centro Estadual de Educação Tecnológica Paula Souza, São Paulo, 2018. Disponível em: http://www.pos.cps.sp.gov.br/dissertacao/a-pesquisa-aplicada-e-a-inovacao-tecnologica-na-educacao-profissional-desdobramentos-no-instituto-federal-de-educacao-ciencia-tecnologia. Acesso em: jul. 2021.

Elmôr Filho , G; Sauer, L. Z.; Almeida, N. N.; & Villas-Boas , V (2019). Uma Nova Sala de Aula é Possível - Aprendizagem Ativa na Educação em Engenharia: LTC.

Rompelman, O. (2000). Assessment of student learning: evolution of objectives in engineering education and the consequences for assessment. European Journal of Engineering Education, 25 (4).339-35.,doi.org/10.1080/03043790050200386

Tiwari R, Arya R.K,& BansaL M.(2017) Motivating Students for Project-based Learning for Application of Research Methodology Skills. International Journal of Applied and Basic Medical Research. ;7(1):S4-S7. doi: 10.4103/ijabmr.IJABMR_123_17. PMID: 29344449; PMCID: PMC5769169.

Wankat, P. C.,& Oreovicz (1993), F. S. Teaching engineering: McGraw-Hill.

Upgrading a TurtleBot3 robotics platform to support a Project-Based Computational Robotics course

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Abstract

Many courses in Computer Engineering rely on specific equipment during learning. More specifically, Robotics and Applied AI courses benefit from using real equipment for projects and classroom activities, since simulated environments do not provide the variability of conditions in the real world nor support every feature available in real robots. However, selecting an appropriate robot for use in educational settings is not simple: not only should it be accessible to students that will have their first contact with robots but also it should be able to support each course's learning objectives. In this paper we describe how we adapted the TurtleBot3 (TB3) platform to support a Project-Based Computational Robotics course that focuses on Computer Vision and high-level behavior programming. More specifically, we (I) list common problems we encountered when using TB3 for learning and describe how we mitigated them; (II) developed a robotic arm that can be attached to TB3's body and is available as a ROS topic; and (III) implemented these in the Gazebo simulator, allowing us to both recreate the physical tracks present in the Robotics lab in the simulated environment but also to adapt the course to Emergency Remote Teaching. We also explore how these features of both TB3 and our customizations were used to support Project-Based Learning activities that occur in the last 8 weeks of the course. Students are tasked with a series of robotic missions of increasing difficulty and must create a program to control a robot and achieve these objectives. Each mission corresponds to a certain set of concepts and hardware used in the mission. For instance, a mission corresponding to a Basic (C) proficiency level might only navigate the environment, while more advanced proficiency levels require some interaction using the robotic arm. We describe the missions and environments used in the last semesters and how they map both to our customizations and the courses' learning objectives.

Keywords: Active Learning; Engineering Education; Conference Information; Project Approaches.

1 Introduction

In the field of computer engineering, hands-on learning is considered a valuable and effective approach for teaching and learning. Lectures are useful for conveying theoretical concepts, but practical lab sessions or projects can encourage students to apply their knowledge to real-world problems (Ozuron &, Bicen, 2023). There is a continuous discussion in science education regarding the optimal type of experimental work. While simulations and remote experiments have their advantages, hands-on experiments provide distinctive benefits. (Irigoyen & Larzabal & Priego, 2023). In robotics education, a physical robot is necessary for hands-on or remote experiments.

However, selecting an appropriate robot for educational settings can be challenging (Russell & Norvig, 2010). Within the context of engineering education, it is crucial to choose a robot platform that can effectively support project-based learning (PBL) methodologies. The implementation of PBL in higher engineering education is crucial, as demonstrated in the book "PBL in Engineering Education: International Perspectives on Curriculum Change" (Guerra & Ulseth & Kolmos, 2017). The presented cases highlight the transition from traditional teaching to a more effective approach (Guerra & Ulseth & Kolmos, 2017). This multidimensional and dynamic curriculum change is essential for achieving excellence in engineering education. PBL is an innovative approach in engineering education that emphasizes hands-on, real-world problem-solving. By engaging students in authentic projects, PBL promotes active learning, collaboration, critical thinking, and the practical application of engineering principles. In the specific case of the Project-Based Computational Robotics course focused on Computer Vision and behavior programming, the adaptation of the TurtleBot3 (TB3) platform was undertaken to meet the requirements of PBL-based instruction. The Project-Based Learning (PBL) methodology encourages students to learn actively and collaboratively, working on projects that solve real-world problems and promote the application of theoretical concepts (Almulla, 2020).. The TB3 platform has been developed on the Robot Operating System (ROS), which offers a versatile and robust foundation for building and experimenting with diverse robotic applications such as perception, navigation, and mapping.

With the help of the ROS ecosystem, we have been able to integrate a range of sensors, actuators, and software modules, enabling various applications of the TB3 platform in real-world tasks. We also encountered common problems when using TB3 for learning (Amsters & Slaets, 2019), which we describe and mitigate. In addition, we developed a robotic arm that can be attached to TB3's body and is available as a ROS topic, and we implemented these customizations in the Gazebo simulator, allowing us to recreate the physical tracks present in the Robotics lab in the simulated environment, as well as adapt the course to Emergency Remote Teaching. To support Project-Based Learning activities, we created a series of robotic missions, in which students must create a program to control a robot and achieve specific objectives. Each mission corresponds to a certain set of concepts and skills used in the mission.

We describe the missions and environments used in the last semesters and how they map to both our customizations and the course's learning objectives. By sharing our experiences in adapting the TB3 platform and designing these Project-Based Learning activities, we hope to provide guidance to other educators seeking to incorporate robotics education into their course.

2 Issues when using TB3 for learning and how we mitigated them

2.1 The TurtleBot3

The TurtleBot3 is a mobile robot designed to support education and research in robotics, powered by the open-source Robot Operating System (ROS). ROS provides a flexible and powerful platform for developing and testing various robot applications, including navigation, mapping, and perception. With the help of the ROS ecosystem, it is possible to integrate different sensors, actuators, and software modules to create custom robot behaviors. The Turtlebot3 features a 360-degree LiDAR sensor, OpenCR hardware control board, Raspberry Pi computer, and wheel encoders. There are two main configurations available: the "burger" and "waffle" models. The waffle model is larger than the burger model and comes with an additional camera sensor, making it suitable for more advanced computer vision applications, However, it is also more expensive than the burger model. We can see in Figure 1 the physical structure and available hardware of Turtlebot3 model Waffle Pi and Model Burger. More details about hardware specifications of Turtlebot3 Waffle Pi or Burger model it is available at (https://emanual.robotis.com/docs/en/platform/turtlebot3/features/#specifications).

After selecting the Turtlebot3 Burger, several improvements were necessary to the robot infrastructure to achieve the objectives of the course activities, especially in supporting computer vision, behavior, and mapping tasks. In the following sections, we will discuss these improvements in detail.

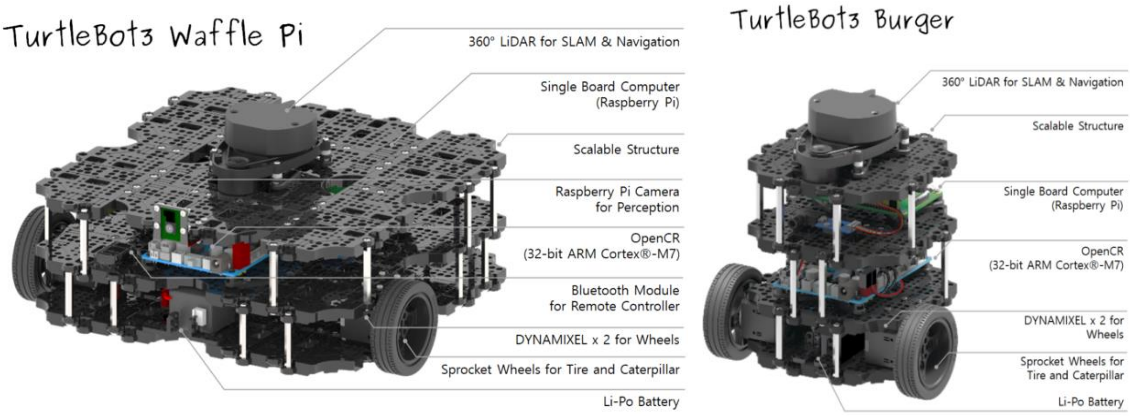

Figure 1. Turtlebot3 Components Presentation, Burger and Waffle Pi model. Image taken from ROBOTIS official documentation.

2.2 Connectivity Issues

When using TB3, establishing a connection between the robot and a computer or network can be difficult, which can hamper programming and testing. The official workflow involves using fixed IP addresses or by connecting a screen to the robot's operating system to capture the IP assigned by the network. To mitigate this issue, a user interface was developed that abstracts the connection dynamics between the Turtlebot3 and the host PC. This interface simplifies the connection process, providing the name of the network that the robot is connected to and the IP address assigned to that robot, also allowing for a much simpler change of network.

In Figure 2 we have an illustration of how the connection between robot and user works. The robot finds the network with the best signal available and displays the SSID (Service Set Identifier) and IP address on the display OLED. With this information the user can connect to the same network as the robot, or choose another available network through the UI (User Interface). In the url (https://www.youtube.com/watch?v=bGi5jZc8NP) we have a video that demonstrates the application of the UI and how to interact with the screen.

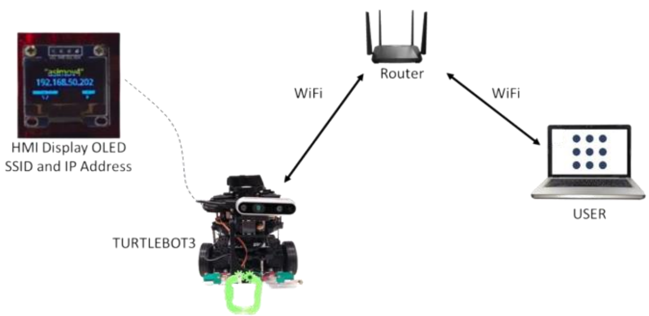

Figure 2. Image with the network interface diagram.

2.3 A Latency Network Issue:

When the number of students in the class grew, even with 6 access points available for exclusive connection to the robots, the network latency was high, because of the data traffic from the sensors, likely because of video streaming from the robots to the students' computers. To fix that, the turtlebot was configured to provide an Ad-hoc network, allowing each student to have an individual network with the robot, which significantly improved latency.

2.4 Sensor Issues:

TB3 Burger comes only with the 360 LIDAR sensor and the IMU sensor by default, which may not be sufficient for activities involving computer vision, autonomous behavior and robot interaction with objects in the environment. To meet these requirements, we added a camera, some mechanical shock sensors (bumpers), and a robotic arm to the robot. Specifically, the RaspCam V2 RGB camera was added to address challenges related to mapping, shape, color, and object recognition..

In Figure 3 we have the rendering of the images published via GSCAM from the robot to the Host PC and the physical installation of Raspicam V2 on the TB3.

Figure 3. TB3 with the Raspcam installed and the display of the image captured by the robot camera.

2.5 Limited processing power:

The Raspberry Pi 3 that came with the kit had processing limitations, which could deteriorate the robot's performance. To address this issue, the Raspberry Pi 4 with 4GB of RAM and a more powerful processor were implemented.

3 Recreating Physical Tracks in a Simulated Environment

The COVID-19 pandemic forced many educational institutions to shift their teaching methods from face-to-face to virtual settings. While this presented significant challenges, it has also provided opportunities to explore alternative learning resources that were previously underutilized. In particular, virtual scenarios have become a valuable tool,especially Robotics and Applied AI courses. These virtual environments enabled a more comprehensive exploration of scenarios that would be difficult to replicate in the real world, such as high contrast environments to facilitate computer vision activities. In figure 4 we can see the environments provided by ROBOTIS (Manufacturer of Turtlebot3) and the turtlebot3 model burger simulated in the gazebo, available on repository (https://github.com/ROBOTIS-GIT/turtlebot3_simulations).

Figure 5 shows some of the environments we develop focusing on tracks with high contrast and different features that are challenging to replicate in the real world.

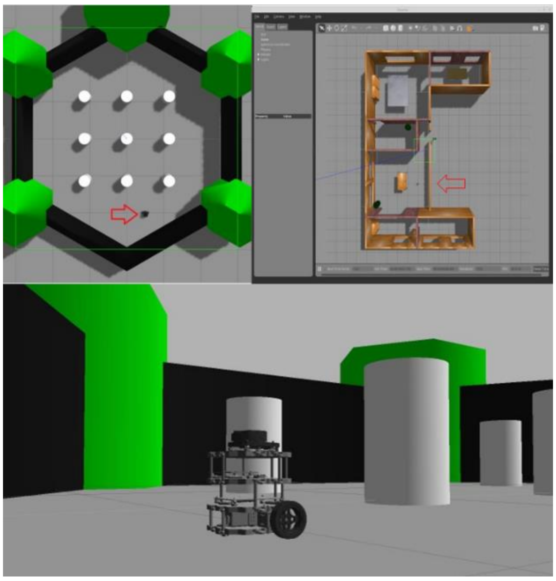

Figure 4. Simulated environment in the gazebo turtlebot3 world on the left and turtlebot3 house on the right, the Turtlebot3 Burger model available from ROBOTIS at the bottom of the image.

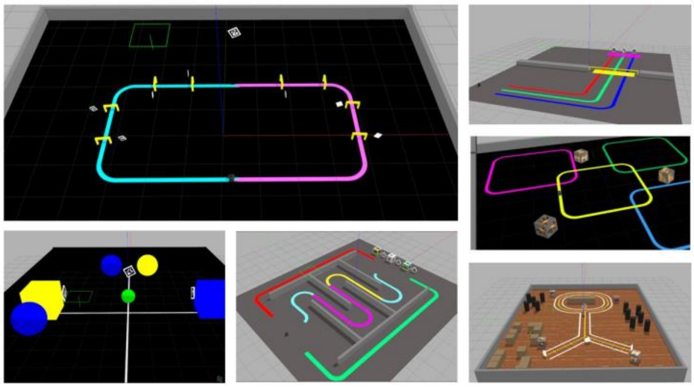

Figure 5. Some of the created scenarios. All created tracks are available in this repository https://github.com/insper/insperbot.

3.1 The Gazebo software

The Gazebo software was implemented to virtualize the robot and laboratory due to the COVID-19 pandemic, which made it impossible to use the physical infrastructure. The default scenario available in Gazebo with the TB3 burger is heavy for processing and limits the experience since it does not come with a camera, robotic arm, and objects with physics prepared to interact with the robot. To work around these problems, we recreated the scenarios with objects prepared for interaction with the robot creating valuable learning experiences. Our adaptations have enabled us to recreate the physical tracks present in the Robotics lab in a simulated environment, which allowed us to adapt the course to Emergency Remote Teaching. These virtual scenarios made it possible for the practical activities and the hands-on format of the course to be maintained during the time of isolation. In addition, Project-Based Learning activities, including robotic missions of increasing difficulty, were supported using these features of TB3 and our customizations. In Figure 6, we present the following elements: a) the simulated TB3 with the proposed adaptations and developments by our team, b) the larger image on the right represents a third-person view of the custom-developed map with challenging elements for robot detection through the maze using color segmentation, 3D marker detection, and object recognition via neural networks. The smaller images above show the robot's first-person perspective, and the image below displays the operating system terminal with real-time system logs.

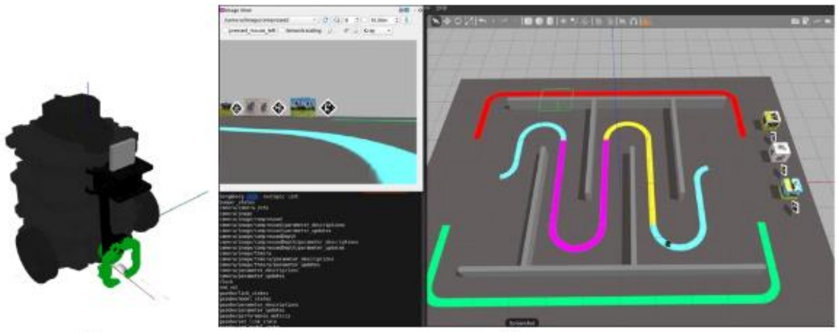

Figure 6. TB3 with the features implemented in the simulator and the display of the camera and the simulated environment.

4 Projects and activities that were made possible by the listed implementations

4.1 Self-preservation Activities

Self-preservation behavior is essential for robots that operate in unpredictable and hazardous environments, such as search and rescue missions or industrial applications. Robots should be able to navigate and avoid obstacles, ensuring their own safety while completing their tasks. Besides TB3's original sensors (360-LiDAR and IMU), the addition of the bumpers and camera provide many more opportunities to create behaviors that involve self-preservation.

- Detect an object present in the camera (using color or MobileNet[1]) and follow/move away from it. An alternative is to detect two types of objects and react differently to each type.
- Use background subtraction techniques to identify objects moving in the scene and track them. The robot can rotate to keep the desired objects in the viewport.
- Move through a determined path avoiding objects (boxes) of certain colors. This can use both the camera and the LiDAR sensors to detect objects and estimate their distance to the robot
- Use a state machine to represent when the robot is in danger, in which case it tries to move itself out of danger. Transitioning between states is done by analyzing LiDAR, camera and bumpers.
- Use a state machine to make a robot respect semaphores. Red and green lights are identified by the camera. Two states exist: “walk” and “wait at the semaphore”

These examples can both be used as in class activities or be composed into larger projects. They involve more than one type of sensory input (camera, LiDAR and bumpers) and can result in behavior as simple (run away/follow) or complex (state machines) as necessary. In Figure. 7 we can see the robot performing a student's activity, where the robot performs the behavior of running away from the bottle, in the link it’s possible to see the complete scene. https://youtu.be/wbfAsjTZru0 . In Figure 8 we can see the robot executing a student's activity, where the robot performs the following behavior: the red circle in the center of the image represents the robot's target, both the cat and the bicycle. In the link we can see the complete scene. https://youtu.be/tqNp4_4tdiQ.

[1] MobileNet is a convolutional neural network architecture that was designed for mobile and embedded vision applications (Sandler, Howard, Zhu, Zhmoginov & Chen, 2018).

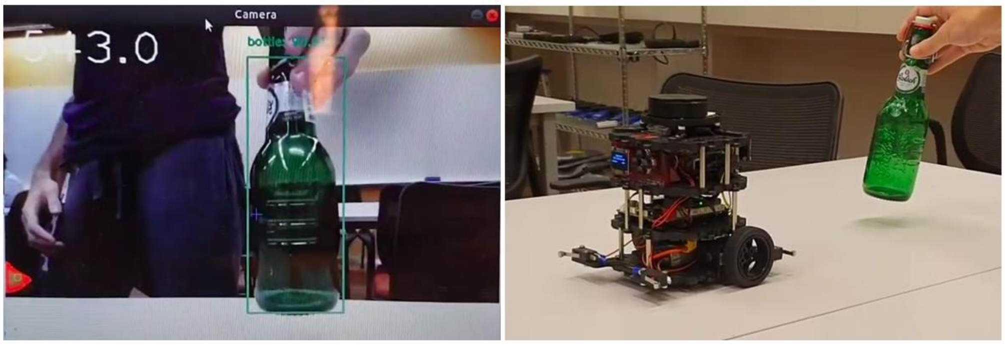

Figure 7. robot correctly detects a bottle and runs away from it

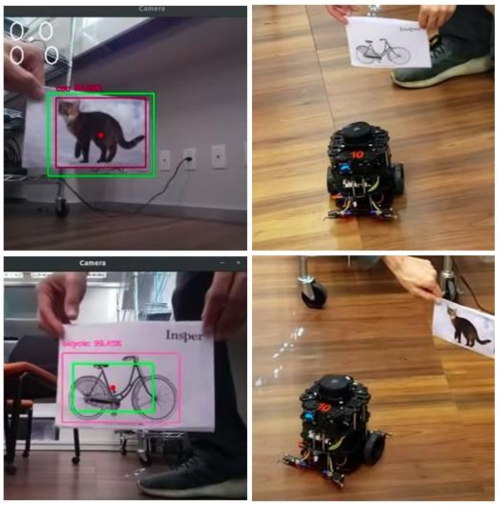

Figure 8. robot correctly detects the objects and marks the target to be followed with a red circle.

4.2 Navigation and Interaction with Objects - Simulated TB3-Burger (Performed during the 2020 pandemic): To overcome the limitations of practical activities during the pandemic scenario, the virtual environment created promotes active learning and skill-building in the field of robotics and programming. The activity was designed with three levels of difficulty, allowing the participants to gradually develop their skills and knowledge of computer vision, robot programming, and object detection. By actively engaging in the activity, the students were able to enhance their understanding of these concepts while interacting with a virtual environment.

- The track is marked with contrasting colors, and the robot uses advanced techniques such as point of escape, shape, and color detection with the help of a camera, IMU sensor, and 360-LIDAR laser to map and navigate the scenario while staying on track.
- The environment includes boards with ArUco markers strategically placed along the track and on the objects known as "creepers." These markers enable the robot to identify and locate objects using a unique ID for each object. This information is critical for object identification.
- The robot is required to traverse the track, identify the objects called "creepers" by their color and ID, and locate the boxes containing objects categorized by the Mobilenet. After mapping the location of the boxes and creepers, the robot must collect the creeper with the correct ID and color (randomly chosen) and deposit it near the box with the object also randomly chosen. Advanced techniques of

behavior, mapping, color segmentation, and artificial intelligence (using the Mobilenet) are necessary to accomplish the task.

The combination of these features creates a complex and dynamic environment for the robot to navigate, identify and manipulate objects. This provides an opportunity for students to actively engage in the activity, enhancing their understanding of robotics and programming concepts while developing skills in object manipulation. The Navigation and interaction with objects activity proved to be an effective way of promoting active learning and skill-building in the field of robotics and programming, promoting active learning and skill-building in these fields despite the challenges posed by the pandemic. In Figure 9 we can see the robot playing a student's program, after randomly selecting an ID and color for creeper and an animal for the deposit boxes, the robot looks for the creeper of the ID and color chosen, captures the creeper and takes it to the deposit box marked by the animal selected. In the link below we can see the complete scene. https://youtu.be/TQPLV2kHsoU.

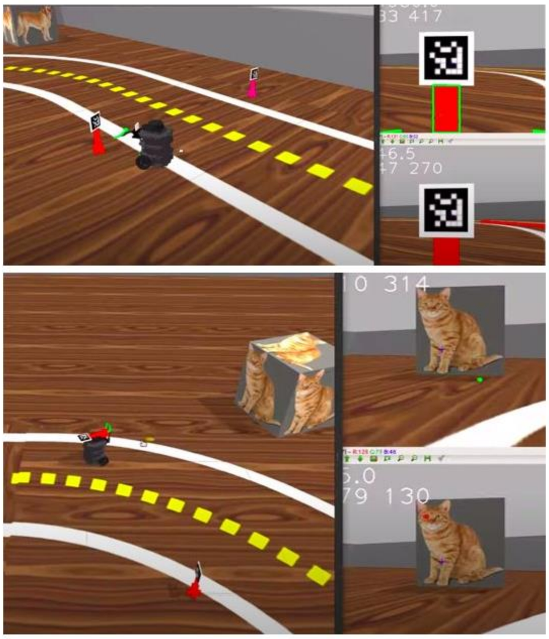

Figure 9. presented a simulated scenario in which a robot successfully identifies and captures a Creeper. Subsequently, the robot proceeds to transport the Creeper to a designated box containing a randomly selected object.

5 Conclusion

The implemented solutions enabled various projects and activities, providing students with valuable opportunities to explore and apply concepts of robot behavior, self-preservation, navigation, and interaction with objects. Through these activities, students were able to develop their problem-solving skills and creativity while gaining a better understanding of how robots operate in real-world scenarios. The activities presented different difficulty levels, allowing students to progress from basic to advanced concepts of robot behavior and self-preservation. The rubrics provided clear guidance on relevant topics and learning objectives, ensuring that the activities were both engaging and educational. These activities offered students practical experience and reinforced the concepts covered in class.

The hands-on nature of the activities allowed students to explore and experiment with different approaches to solving challenges, developing their problem-solving skills and creativity. The navigation and interaction with objects activity using the simulated TB3-burger was particularly innovative, overcoming the limitations of practical activities during the COVID-19 pandemic. Overall, the listed implementations have provided students with valuable opportunities to explore and apply concepts of robotics.

The infrastructure developed to enable the practical activities and the learning experience with the TB3 during social distancing due to pandemic proved to be an excellent tool to support the activities in the lab. Even with the end of social distancing, by using the simulator to develop the algorithms, the students are given the possibility to mature the code inside the simulator, which makes it possible to optimize the time in the lab with code validation tests and finer adjustments.

6 References

Ozuron, N., Bicen, H.:(2023) Does the inclusion of robots affect engineering students achievement in computer programming courses? J. Math. Sci. Technol. Educ. 4779–4787

Irigoyen, E., Larzabal, E., Priego, R.: (2023) Low-cost platforms used in control education: an educational case study. In: 10th IFAC Symposium Advances in Control Education, pp. 256–261

Epuck. e-puck education robot (2014). http://www.e-puck.org.

ADEPT. Adept Mobile Robots (2014). http://activrobots.com.

Russell, S., & Norvig, P. (2010). Artificial Intelligence: A Modern Approach, 3rd ed. Prentice Hall.

Szeliski, R. (2022). Computer Vision - Algorithms and Applications, Second Edition. Springer, Texts in Computer Science.

Montagner, I., Miranda, F., & Hashimoto, M. (2018). Customizing rubrics to enable open-themed projects in robotics and AI. In Proceedings of PAEE/ALE 2018, NordiCHI (pp. 376-383). Brasilia, Brasil.

Guizzo, E., & Ackerman, E. (2017). The turtlebot3 teacher [resourceshandson]. IEEE Spectrum, 54(8), 19-20.

Quigley, M., Conley, K., Gerkey, B. P., Faust, J., Foote, T., Leibs, J., Wheeler, R., & Ng, A. Y. (2009). ROS - an open-source robot operating system. In ICRA Workshop on Open Source Software.

Amsters, R., & Slaets, P. (n.d.).(2019) TurtleBot3 as a Robotics Education Platform. Robotics in Education: Current Research and Innovations, Advances in Intelligent Systems and Computing, Volume 1023, Katholieke Universiteit Leuven.

Almulla, M. A. (2020). The Effectiveness of the Project-Based Learning (PBL) Approach as a Way to Engage Students in Learning. SAGE Open, 10(3). https://doi.org/10.1177/2158244020938702

Sandler, M., Howard, A. G., Zhu, M., Zhmoginov, A., & Chen, L.-C. (2018). Inverted Residuals and Linear Bottlenecks: Mobile Networks for Classification, Detection and Segmentation. CoRR, abs/1801.04381. Retrieved from http://arxiv.org/abs/1801.04381

Guerra, A., Ulseth, R., & Kolmos, A. (Eds.). (2017). PBL in Engineering Education: International Perspectives on Curriculum Change. SensePublishers Rotterdam.

Remote Laboratory Concepts and Practices during the COVID-19 Pandemic: An Experience Report

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Abstract

Distance learning courses on electronics have been available in Brazil with many schools catering to millions of students of varying sizes. Typically, these schools provide educational kits consisting of electronic devices and didactic material, allowing remote students to develop projects independently. With the emergence of the COVID-19 pandemic, many traditional engineering schools were required to innovate and transform their approach to education, serving their students solely through distance learning. The necessary changes could not be planned due to the sudden closure of laboratories in educational institutions. Consequently, it was necessary to address pertinent questions and make timely decisions to continue offering the quality of face-to-face education in a remote setting during the semester.

This report aims to present and discuss a remote teaching approach based on three fundamental principles: (i) delivering course concepts remotely using same time of face-to-face classes, (ii) executing similar face-to-face instruction practices in a remote setting, and (iii) providing supplementary support to students in their practices and development of discipline-specific concepts and projects.

To facilitate this approach, the existing projects and devices in the discipline's laboratory were transitioned into a didactic support material kit tool used for emergency remote teaching course. This kit responded to the pedagogical and didactic aspects of face-to-face classes but transmitted remotely while preserving the learning-to-learn aspect involved through the face-to-face laboratory approach.

A kit of support material consisting of electronic devices and boards was employed to successfully implement the project-based learning approach throughout the semester for remote practice. This approach allowed the students to gain insights into laboratory concepts and practices that were typically executed in a face-to-face setting.

Keywords: Educational challenges during crisis, Experiences on Active Learning and PBL in engineering education.

1 Introduction

Current technologies, advances in mobile telephony and internet in Brazil, the ease of asynchronous learning, and the recent COVID-19 crisis experienced by brazilian population have further stimulated the growth of remote education in Brazil. According to data from the Brazilian federal government, distance learning mode had a positive variation of +23%, with almost three times the number of enrolments compared to in-person undergraduate courses in the 2020-2021 biennium. The São Paulo State Virtual University (Univesp) stands out from the expansion observed in recent years, according to official data from the state government (Inep, 2022). It is worth noting that remote courses have been a reality in Brazil since 1939, when the first course of the then Instituto Radiotécnico Monitor pioneered the development of distance learning, with electronics experiments and practical assemblies in the form of kits, cited in "The first course offered by Instituto Radiotécnico Monitor was made up of handouts and a kit that allowed, at the end of the training, the construction of a simple homemade radio model." (Monitor, 2023).

Among several more recent authors, we can consider the work of a MOOC-type distance learning course to practice and didactic experience of microcontrollers through "Embedded Systems - Shape The World", where the teaching of techniques and laboratory classes were transmitted through the edX course platform and kits were applied (Valvano, 2014).

Since the beginning the Electronic Systems and Microprocessors course has a different approach from others embedded systems courses since the class is in person and for mechatronics engineering students. In the following three years after the begining of the course in 2017, its classes and practices (here refered as studios) were updated aiming its integration with the partner discipline of Mechatronics Project, which is still nowadays a required course for students of mechatronics engineering. This class profile had its sequence polished and more recently used successfully remotely during the COVID-19 crisis.

Imagine we are in the year 2020, which started normally, but soon news arrived from abroad indicating that a health and medical crisis was taking place in Europe, particularly in Italy, and there were already reports of blockades in certain regions in China. Shortly, at the end of February 2020, Brazilians were already following the distance of events that would culminate in March, the appearance and increase of COVID-19 cases in Brazil. Insper took protective measures and, to plan its next steps at the beginning of the COVID-19 crisis in Brazil, closed its campus for three days, forcing the suspension of its classes.

For three consecutive days in March, before the campus and engineering laboratories completely closed their doors, the technical team of the Mechatronic Systems Laboratory began to raise and update its stock of components and electronic devices. In three days, successfully implemented a homemade solution for making a discipline material kit that was separated, prepared, and delivered to enrolled students in that semester.

This kit aimed to support the PBL (project-based learning) approach developed in the discipline and in the integrated studios with Mechatronic Project, maintaining practical classes during the period of remote teaching, outside the physical campus. Other reports in the literature point to gains in the emphasis on practical approach (Shoufan, 2021), (Kohl, 2015).

Figure 1 shows the result of the effort in assembling the kits over a period of three days in 2020. The second version of the kits, which was subsequently prepared with more time during the academic recess included a dedicated box, more electronic components and tools dispatch to students, still using emergency remote teaching, in the year 2021, is seen in Figure 2 and Figure 3.

Figure 1. 2020 kits

Figure 2. 2021 kits

Figure 3. The 2021 kit.

In the following pages we present the concepts adopted, which allowed our students to adapt the previous practices in the laboratory of electronics to the Emergency Remote Teaching.

2 Scope

The aim of this article is to present in a summarized way the three key points that form the three basic pillars of the remote teaching methodology offered during the COVID-19 crisis in 2020 and 2021: (i) offer the course concepts at the same times as the in-person classes, but remotely; (ii) work on the in-person practices, but remotely; and (iii) offer extra-class support to the students in their practices and development with the concepts of the course.

The academic management of Insper, as an institution, formulated a resolution to the professors, the technical support of the laboratories, and their students that, as a teaching methodology, remote classes would be offered on the same days and times as in-person classes. In this way, (a) the concepts in the classes would be maintained with small adjustments, and (b) the remote practices would have to be fitted in and have the same duration as the available weekly class schedule for the course. The extra-class (c) support traditionally taking up 1.5 hours/week, brought new challenges to the teaching staff and technical support, which will be further discussed in the next topic, regarding the methodology used and the handling of the kit in remote classes.

It is worth noting that we do not simply send a package of experiments and a written script and ask students to return a completed report, as in the old courses. Our proposal was to show that classes had scheduled times, consultations with scheduled times, with a team, in addition to a script already provided, containing objectives, theoretical foundations, resources used and evaluation of results, and even with real-time assistance in these periods. of activity. This was an effort and constant learning by the team of teachers, their assistants and technicians in emergency remote teaching.

3 Methodology

Both theoretical end expository practical classes were conducted through simultaneous connection by MS Teams under a planned schedule.

Supporting time after classes were extended and scheduled with a team consisting of main teachers, assistant teachers and laboratory technicians to assist students with theirs basic theoretical and practical issues, as well to install software tools and understand the experiment kits provided.

To improve class performance, students were divided into two smaller classes, and the discipline was thus presented twice in a day: first during regular hours from 7:30 am to 9:30 am, and the second half of the class from 9:45 am to 11:45 am. The initial gain was the expanded support, reaching a ratio of approximately 12 students to 4 teachers and technicians online at the same time via Teams. An average of 3 students per every support person.

With the sudden change to the remote format, some of the solutions already implemented in the course, like "Minha Biblioteca," a virtual environment with e-books available to students was emphasize. At the beginning (2020), the kit resources seemed limited compared to the classic laboratory material, but throughout the lectures and practices, they proved to be adequate and slightly improved in the kit of the new remote edition (2021). The initial lectures and practices in March 2020 were revised and always presented with the help of the kit material. Now, they were accompanied by the methodological use of short videos, such as topics on semiconductors (Figure 4).

The didactic load with the Proteus simulator was increase (Figure 5), since it is highly interactive for simulating analog and digital electronic circuits. It is worth noting that Insper's partner company, the English Labcenter, soon made a cloud-based remote license version available for the program without the need for the student to physically take the computer to Insper's technicians to install and maintain their academic license. Another resource emphasized in the remote format, was to present the circuits through the Fritzing program (Figure 6).

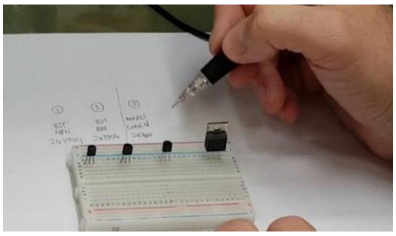

Figure 4. short transistor vídeo

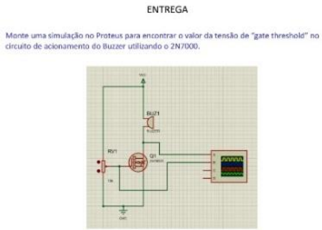

Figure 5. Proteus Simulator

Figure 6. Fritzing Program used in slides

During the remote practical classes, a methodology for online transmission of instrumented results was carried out by the professor through the use of the Analog Discovery equipment and the Waveforms program from Digilent, using Teams. The student could pick up the equipment at the library, just as one would pick up a book. This resource already existed as a pedagogical technology provided by Insper.

With the Teams environment being massively used in classes, both by educators and students, the triad presented in the Scope of this article proved to be complete. Now it was necessary to refine the didactics so that the results could be achieved. Simple practical classes, such as activating a 7-segment display, were explored in multimedia and online format, where students could interact and present satisfactory results on their learning performance. Each student had to present a short video about the practice developed individually, remotely.

An example was to encourage mechatronic engineering students with projects that were close to the resources they have in their remote location, such as the case of contextualizing the control panel of a washing machine, a classic mechatronic household automation equipment (figure 7). Its panel contextualized a human-machine interface (HMI), and the student's project consisted of simple things like creating software programming of the embedded system using the STM32 microcontroller, through the NUCLEO-F103RB board from the kit (figure 8). This firmware had to be reproduced by the student and presented in a short video (figure 9), submitted via the Blackboard environment. The student's feedback on what they achieved in the remote practice came after the class via Teams.

Figure 7. Real washing machine appliance panel.

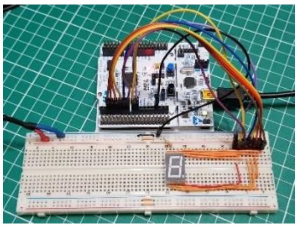

Figure 8. practical challenge.

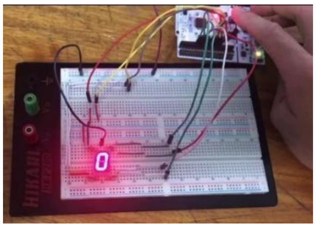

Figure 9. student implementation

These simple practices formed the standard of the didactic-pedagogical methodology used in remote classes. For example, a class on logic gates, which is part of the conceptual content of combinational digital logic systems, is presented in the following sequence: Figure 10 show a simulated circuit with students using Proteus, Figure 11 is the practical challenge presented through Fritzing, and Figure 12 shows the practical result of the implementation on a breadboard. Using these simple practices and the original class time, the semester took shape with satisfactory results and performance above what was expected at the beginning of the kit creation and migration to remote teaching. The curriculum and concepts taught in the syllabus were explored.

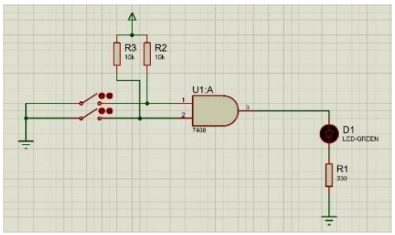

Figure 10. Logic Gate Proteus Simulation

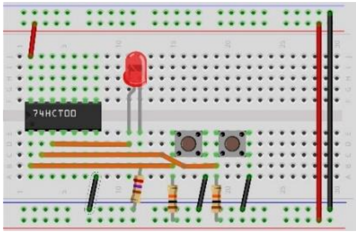

Figure 11. Fritzing Circuit on Protoboard

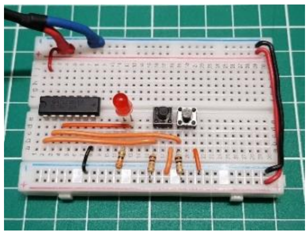

Figure 12. Real Protoboard implementation

studio classes, of 4-hour in the morning, had an initial part reserved to present the concepts and materials of the kit for practice (Figure 13), using the classic slide presentation previously mentioned, but interactive with remote students, and the operation of the circuit of the studio. Moving on via Teams to the assembly with kit items, such as stepper motor control modules (Figure 14) and remote student interaction and their implementations (Figure 15).

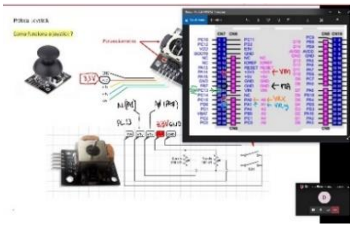

Figure 13. Remote class studio presentation.

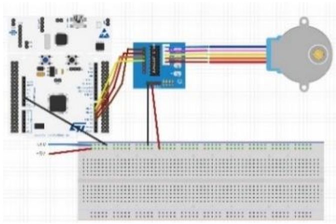

Figure 14. Remote class challenge proposed.

Figure 15. presentation of student results via Teams.

A good number of students showed motivation and successfully interacted with teachers and technicians in the discipline.

4 Practical results

The practical results from the interactions between theory and practice with students in topics such as digital logic concepts from Boolean algebra and Karnaugh map techniques in the design of digital combinational-sequential logic circuits can be seen in the expository approach of remote classes (Figure 16), and in the student office hours (Figure 17). The progress of students' results was observed. For example, in the supervised practical activity (APS), which was outside of class hours, students were exposed to a challenge related to sequential digital logic content and had to solve a project. The operation of a stepper motor by a logic circuit with integrated circuits was simulated and its operation was demonstrated through the implementation in Proteus, and the student presented the complete simulation (Figure 18) submitted via the Blackboard environment.

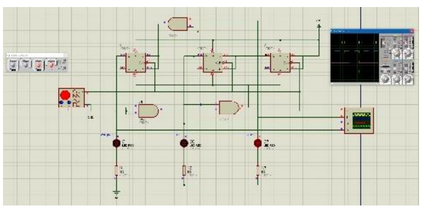

Fig 16: Remote Class Circuit Simulation.

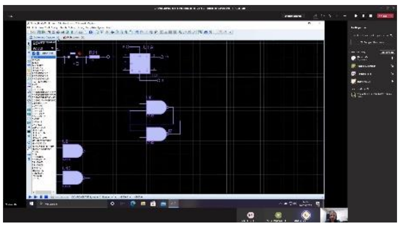

Fig 17: Student Simulation Support, using Teams.

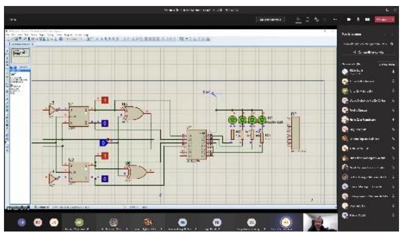

Fig 18: Student APS final result presentation using Teams.

In addition to the APS projects, the learning objectives were also addressed through a project challenge in the course, in the form of a function generator, and the creation of specific firmware (for the STM32F103RB microcontroller) programmed in the C language using Arm mbed online compiler environment. In the first edition of the kit in 2020, practical results were achieved by students in the development and prototyping of a 3-bit R-2R digital-to-analog converter (DAC) with total success. The project also included the virtual presentation (Figure 19) of an Arduino UNO® type shield board student project to be plugged into the NUCLEO board of the kit. Students then had to create their programs and change the type of signal at the output of the function generator, presenting their work to the teacher at the end of the semester (Figure 20). Students who did not have access to the laboratory bench oscilloscope or the Analog Discovery equipment were able to use resources such as the serial plotter in the Arduino integrated Development Environment (IDE) during their presentation (Figure 21).

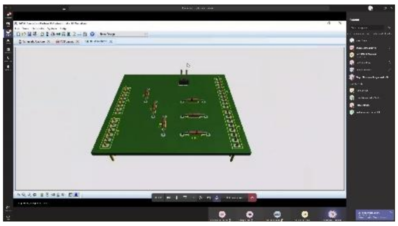

Fig 19: Support on PCB implementation in Proteus.

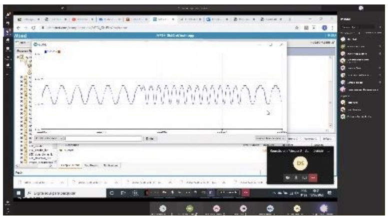

Fig 20: DAC R-2R 3-bit Signal Generator Support.

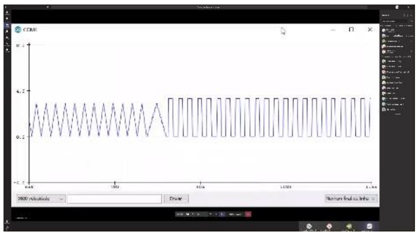

Fig 21: Remote Signal Sampling Capture Presentation.

Given the success of the results, in the following year, 2021, the kit allowed the achievement of a higher-resolution 4-bit and 8-bit R-2R DAC project.

Other challenges, such as the Mechatronics Project partnership, had excellent results with students motivated in their practical projects. Practice with small codes on the LCD Shield module (Figure 22) was incorporated by students into integration projects with other kit resources and items (Figure 23) and were even presented via Teams in the prototype project follow-up classes and virtual PCB manufacturing at the end of the semester (Figure 24). The practical results culminated in the presentation of embedded systems projects with microcontrollers applied in the mechatronics project, through the joint disciplines, and the 4h-hour in the morning remote studios.

Fig 22: remote LCD Shield practical class.

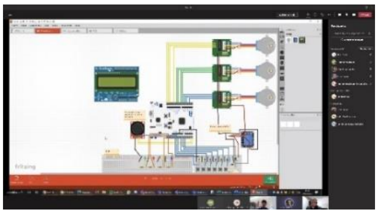

Fig 23: Student virtual presentation, using Teams.

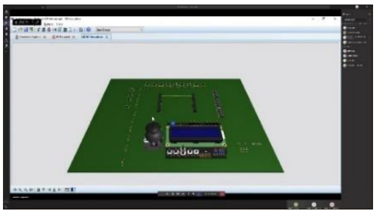

Fig 24: Student CAD presentation, using Teams.

It is worth noting that such educational results were achieved even when the conditions of each student in their remote location (some since the first day of remote classes) already informed us that they were using the family kitchen, among other things, and some had to stop studying in the evening because they worked in shared rooms with other family members in the same residence. Despite the counterpoints that the COVID19 crisis imposed on Insper students and educators, the results were excellent and can be observed, for example, in the complex schematic developed and presented by the student (Figure 26), in the virtual development of the prototype (PCB, Figure 26), and in the physical presentation via the student's camera, remotely (Figure 27).

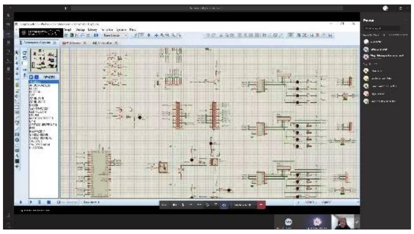

Fig 25: Student Proteus Schematic presentation.

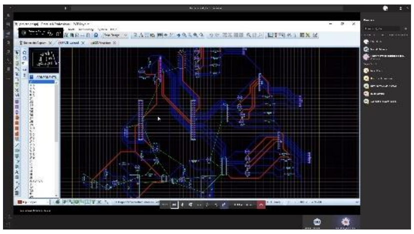

Fig 26: Student Proteus PCB support using Teams.

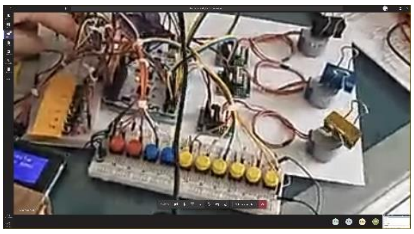

Fig 27: Student Prototype presentation using Teams.

Many students were motivated by the results achieved with the mandatory items in the kit (2020/2021) and were able to advance in optional items that were added to the 2021 kit, such as coding and prototyping a graphical display.

5 Conclusion

It is the consensus of the authors of this article that in recent years, the three basic pillars indicated and intended in the scope were achieved by offering the course concepts remotely within the scheduled times of the face-to-face classes, with the recording of videos of the classes using the annotated slides as a blackboard by the discipline professor, as well as making this material available as a complementary form of remote classes, enriching the support material. The originally face-to-face practices were achieved in the remote format, both through the formatting of the experiments with the kit's support, and through the massive extra-class support provided to the student during their practices for the development of concepts and projects of the discipline.

Many reflections on the approaches of the didactic experiences reported here have been expanded in the market, with new versions of software, such as the increase in resources of programs like TinkerCAD, the greater complexity arising in the environment like Arduino, and in the evolution of the mbed environment now used through the Arm Keil Studio Cloud with Insper students. This is a reflection that, through self-taught or directed study, the student and also the "maker profile" increasingly have space in the environment of modern engineering and in the virtualization of projects, whether in a pressing Industry 4.0, or through the new resources and technological requirements that arise each year.

The authors thank all the rest assured support that Insper, through the course coordination, colleagues, peers facing the same challenges of remote teaching, and the institution's board and council supported and allowed the work in the restricted remote format to maintain quality in the practices of the discipline.

The results of the didactic experience of remote teaching of laboratory practices during the COVID-19 crisis in the years 2020 and 2021 in this discipline were recently reviewed during the Capstone Project at Insper' mechatronic engineering students, and could once again show their positive results during the COVID-19 crisis, in the absorption of the concepts discussed in remote classes, or those project topics necessary for performance and approval. The class that took the Electronic Systems and Microprocessors discipline in 2020 graduated now at the end of 2022.

6 References

Inep (2022, November). Censo da Educação Superior 2021. Divulgação dos resultados. Diretoria de Estatísticas Educacionais. Ministério da Educação.

Kohl, C. Et Al (2015, June) Diversified Projects in Microcontroller Class Enhances Undergraduate Students' Learning, Design and Research. 122nd ASEE Annual Conference & Exposition.

Monitor, Instituto (2023, April). Quem Somos - A escola pioneira no Brasil a desenvolver a educação a distância como modalidade de estudo. https://www.institutomonitor.com.br/quemsomos.

Shetty, D., & Giriyapur, A. C. (2013, June), A new approach in Mechatronics Education through Project Based Learning by International Collaboration Paper presented at 2013 ASEE Annual Conference & Exposition, Atlanta, Georgia. 10.18260/1-2—19092 https://peer.asee.org/a-new-approach-in-mechatronics-education-through-project-based-learning-by-international-collaboration.

Shoufan, A. (2021, March). Active Distance Learning of Embedded Systems. IEEE Education Society Section.

Univesp (2023, April). Univesp: ensino a distância, gratuito, de qualidade e em expansão. https://www.saopaulo.sp.gov.br/ultimas-noticias/univesp-ensino-distancia-gratuito-de-qualidade-e-em-expansao.

Valvano, J. W. (2014, June), Embedded Systems - Shape The World Paper presented at 2014 ASEE International Forum, Indianapolis, Indiana. 10.18260/1-2—17177 https://peer.asee.org/embedded-systems-shape-the-world.

Institutionalization of University Extension through Integrative Projects: An Experience between a Food Industry and the Production Engineering from Mackenzie Presbyterian University

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Abstract

The insertion of the university extension in academic curriculum has been a theme that arouses interest and provokes discussions in the academic sphere, mainly about how to put it into practice. The current legislation, through the Guidelines for Extension in Brazilian Undergraduate Education, regulates the academic activities of extension of undergraduate courses, in the form of curricular components. In this context, Mackenzie Presbyterian University (MPU) has been working extensively to comply with legislation to promote the social, economic, and cultural development of students through the extension activities. The Production Engineering course was the first from the MPU to propose the so-called Integrative Projects (IP), an academic activity of extension. The IP is a multidisciplinary project in which teachers and students, previously enrolled, work together with professionals from a partner company to solve a real problem. During the academic semester, the company's professionals present the problem and monitor the progress of students with the responsible teachers. The methodology allows the students to be the protagonist in the development of their knowledge and in the search for solving the problem. This article aims to present a case study of an integrative project carried out in partnership between the School of Engineering – Production Engineering course and a large company in the food industry sector. The project purpose was to map the pallet management process, used by the logistics department. The company's collaboration has been fundamental to the success of the project, allowing students access to data, visit to the distribution center and discuss the problem with professionals. From the students' perspective, the gains were the development of skills that the market seeks. For the industry, the main gains were identification of opportunities to reduce losses and improve the current controls. The project has increased the social bond and transformed education into authentic, relevant, and meaningful.

Keywords: Engineering Education; Active Learning; University-Industry Collaboration; Value Stream Map.

1 Introduction

There is a concern on the part of Undergraduate Education Institutions (UEIs) to adapt to the National Education Plan (NEP), which is in place for the decade of 2014-2024. The NEP includes guidelines related to university extension in the scope related to the inseparability between undergraduate teaching, research, and extension. (Assembleia Legislativa do Estado de São Paulo, 2016)

According to the CNE/CES No. 7 (2018), extension in undergraduate education is an activity that integrates the curricular matrix and research organisation, forming an interdisciplinary, political, educational, cultural, scientific, and technological process that promotes transformative interaction between UEIs and other sectors of society, through the production and application of knowledge, in permanent articulation with undergraduate teaching and research.

Santos (2020) and Silva & Vasconcelos (2006) defined that the curricularisation of university extension is the insertion of extension activities in the curricular matrices of undergraduate courses, operationalised through integrated programmes/projects, which can be considered curricular components according to the current pedagogical projects of the courses.

At the Mackenzie Presbyterian University (MPU), there is a recurring concern with the triad of extension, research, and undergraduate teaching. In the School of Engineering (SE) of MPU, programmes have been developed with the aim of curricularising extension in their courses. Duro et al. (2023) report in their work one of the initiatives to meet the demand of legislation, through three programmes called Academic Triathlon, a programme that allowed working actions in an inseparable way from undergraduate teaching, research, and extension through active methodologies. This programme involved a group of professors from the basic cycle disciplines and professors from specific disciplines, a group of senior students who worked as monitors and mentors of incoming students in engineering courses.

Within this context, integrative projects (IP) are also considered actions that contemplate the demand for curricularisation of extension, seeking transformative and differentiated education to achieve multi and interdisciplinary training of engineering course graduates from MPU. All this effort aims to provide support to young people so that they are able to face future challenges and meet the demands of the professional market. According to IBGE (n.d.), in the 4th quarter of 2022, 29.7% of young people between the ages of 19 and 24 were seeking a job in the professional market; this scenario of job scarcity leads to high competition and is conducive to the training of more capable and qualified professionals for the market (Athayde, 2021).

According to the World Economic Forum report (2023) it is suggested that almost a quarter of existing jobs are expected to change in the next 5 years. The report points to an increasing urgency for the revolution of the requalification of professionals, as well as the need to update 44% of the skills of an individual worker. This scenario of shortage of qualified professionals according to the changes and requirements of the market becomes conducive to the training of more capable and more qualified professionals to meet the new demands that are emerging with the advancement of technology, use of artificial Intelligence and big data, there is also great demand as analytical and creative thinking. These are skills that, in general, can be found in engineers (WEF, 2023).

This article aims to present a case study of an integrative project carried out in partnership between the School of Engineering – Production Engineering course and a large company in the food industry sector. The way of working, interacting, and seeking solutions to the problems presented in the project provided the development of both hard and soft skills in the students involved with this project.

2 Collaborative Integrative Projects

As previously mentioned, there are several activities that are considered part of the triad of extension, research, and undergraduate teaching in the School of Engineering, such as: some Curricular Components, Integrative Projects, Hackathons, Extension Projects, among other activities.

The IP is a curricular component that allows students to integrate content learned throughout the course. It consists of a set of activities based on active learning practices and it is offered in all courses at the SE, providing students with the opportunity to experience specific situations within their field of study. At the end of the semester, students who have participated in an IP, in addition to gaining experience with a dynamic way of integrating students, faculty, basic, specific, and professionalising content, will also receive 30 hours of complementary activities on their academic history.

The activities are planned and focused on both project development and problem-solving. They can be described as a collaborative model between the university and society, aiming to develop the necessary skills for future engineers and meeting the NEP guidelines. The activity called IP was implemented in the SE as an extracurricular activity, where teachers propose a topic of interest or a project to be developed, plan a certain number of meetings (generally, one meeting per week over two and a half months), and students enrol according to the project more interesting to them. One of the main objectives of the IP is to make students the protagonists in building their knowledge from a proposal, encouraging them to study, research, and present suggestions for solutions to the selected problems.

In August 2022, the IP in the Production Engineering course underwent restructuring. This was done by working with a large company and thus facing the challenge of solving real problems that occur in the industry and professional environment. In this context, the company identifies a problem in a specific area and presents it to the students. The project evolves over a period of approximately 14 weeks. The students enrolled in this IP are divided into groups of about 6/7 students, and they discuss, research, conduct company visits, and present a proposed solution to the problem presented by the company.

Table 1 shows the evolution of the IPs in the SE, along with the engagement of teachers and students and the number of projects offered to the Mackenzie community in the SE.

At the School of Engineering, the Production Engineering course was the first one to propose this IP model, aiming to immerse the student in a real-life situation they will face when starting their internship period. The idea is to bring the real world into the academic setting, allowing students to develop skills and competencies that will be important for their careers as engineers.

Table 1. History of Integrative Projects in the School of Engineering.

Year	Total of Integrative Projects	Number of Teachers Involved	Number of Students Participating
2019	26	17	274
2020	11	12	401
2021	31	24	769
2022	32	23	775
2023.1[(1)]	15	21	320

Note: (1) Data on the number of projects, teachers, and students referring to only one semester.

The job market increasingly requires professionals who has certain competencies, known as soft skills, including communication and writing, work ethics, flexibility and resilience, teamwork, initiative, problem-solving, among others, according to Freitas (2022). By participating in the IP it is expected that students will develop these skills, making a difference in their professional performance and making them more competitive to face future challenges in their careers.

3 Method

This is a qualitative, exploratory study in the modality of a single case study. Case study research promotes the understanding of a real-world phenomenon (Yin, 2015). The study involved the stages of project definition and approval, data collection, analysis and discussion of the results. The research question was "How are integrative projects used to develop hard and soft skills in undergraduate students?".

In the planning stage, to enable the exploration of the studied phenomenon, a structured integrative project was sought that could be followed from its conception to the conclusion of a cycle. According to the literature, project-based learning must include six stages: 1) teach content through knowledge and skills, 2) create a need to know important and fundamental content, 3) need critical thinking, problem-solving and collaboration, 4) develop investigation, 5) provide continuous feedback and 6) present or deliver the final product (Picard et al., 2022). Data collection was performed using participant observation techniques throughout the project, interview with the process manager in the selected company and focus group with the participating students. Figure 1 shows all stages of the project.

The partner company for this project is a prominent manufacturer of oven-baked products in South America, founded approximately 70 years ago. It began its operations as a small bakery and, over time, expanded internationally, diversifying its portfolio.

The collaboration between the company and the university focused on the logistics sector. The organisation demonstrated receptiveness and support, facilitating visits to the distribution centre, and providing relevant information. The manager in charge of the logistics sector was helpful and committed to the partnership in solving identified problems.

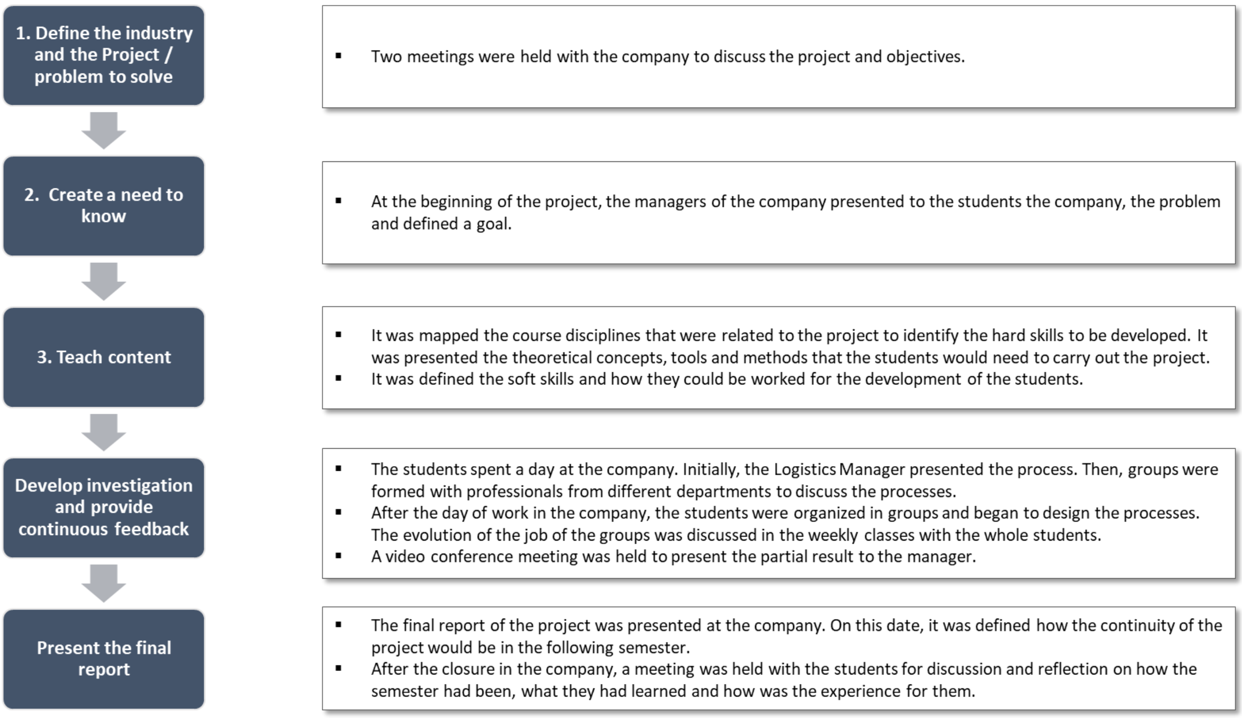

Figure 1. Stages of the Integrator Project.

Additionally, the company participates in socio-environmental responsibility initiatives, engaging in coalitions to combat hunger and food waste (Bastos, 2023). Its international presence spans more than 50 countries and includes a factory in the United States. The company values the concept of family and affection-based relationships in its communication and brand positioning.

4 Results

The IP with the food company, started in the month of August 2022. In total, 30 students signed up to participate in the project.

The details of the project were discussed and agreed between the company's manager in the logistics area and the UPM professors responsible for the project. Initially, 5 UPM professors were involved, among them the coordinator of the Production Engineering course.

The company presented to the team of teachers the logistics area and proposed a project to map the pallet management process and identify opportunities for improvement in this process or the need for restructuring it. The proposal was accepted by the teachers and then a schedule of activities was elaborated for the development of the project with the students in the IP. Within this schedule the following activities were included: presentation of the company and the proposed project, on-site visit, meeting with professionals of the company's department (logistics/pallet management), project development, presentation to the company of the preliminary results, adjustments, and final presentation of the first stage of the project to the company.

Considering the complexity of the process and the high number of departments involved, the company established that the students' goal was to map the current process, the areas involved, all the inputs and outputs of the process.

In the planning of the theoretical knowledge to be developed and its relationship with the disciplines of the Production Engineering course, three of them were identified, namely: Quality Engineering (5th semester), Total Quality Management (7th semester) and Lean Six Sigma (10th semester). From this analysis, the contents that would be presented to the students to help to perform the project were defined: quality tools, method of problem solving, types of waste and map of the value stream. The content was taught in three consecutive weeks.

During the project, two visits were made to the Distribution Centre. The first visit aimed to map, with the support of the teams from all the involved areas, the pallet management system. At this stage, the pallet management system was structured into eight processes as follow: pallet purchasing, pallet inventory control, factory supply, return to the supplier, customer service, carrier service, control of customers of the logistics services provided by the company, and pallet refurbishment. The flows of the eight processes were designed, and the discussion allowed students to understand both the material (pallets) and information flows.

After the visit, students were challenged to draw the macro-process of the pallet management system, consolidating the eight processes, as presented in Figure 2. The flow was done using the Miro application and applying some concepts from the Value Stream Mapping (VSM) method (Rother & Shook, 2012). In the second visit, all the flows of the eight processes and the macro-process were presented by the student coordinators of each process team to the company's area managers.

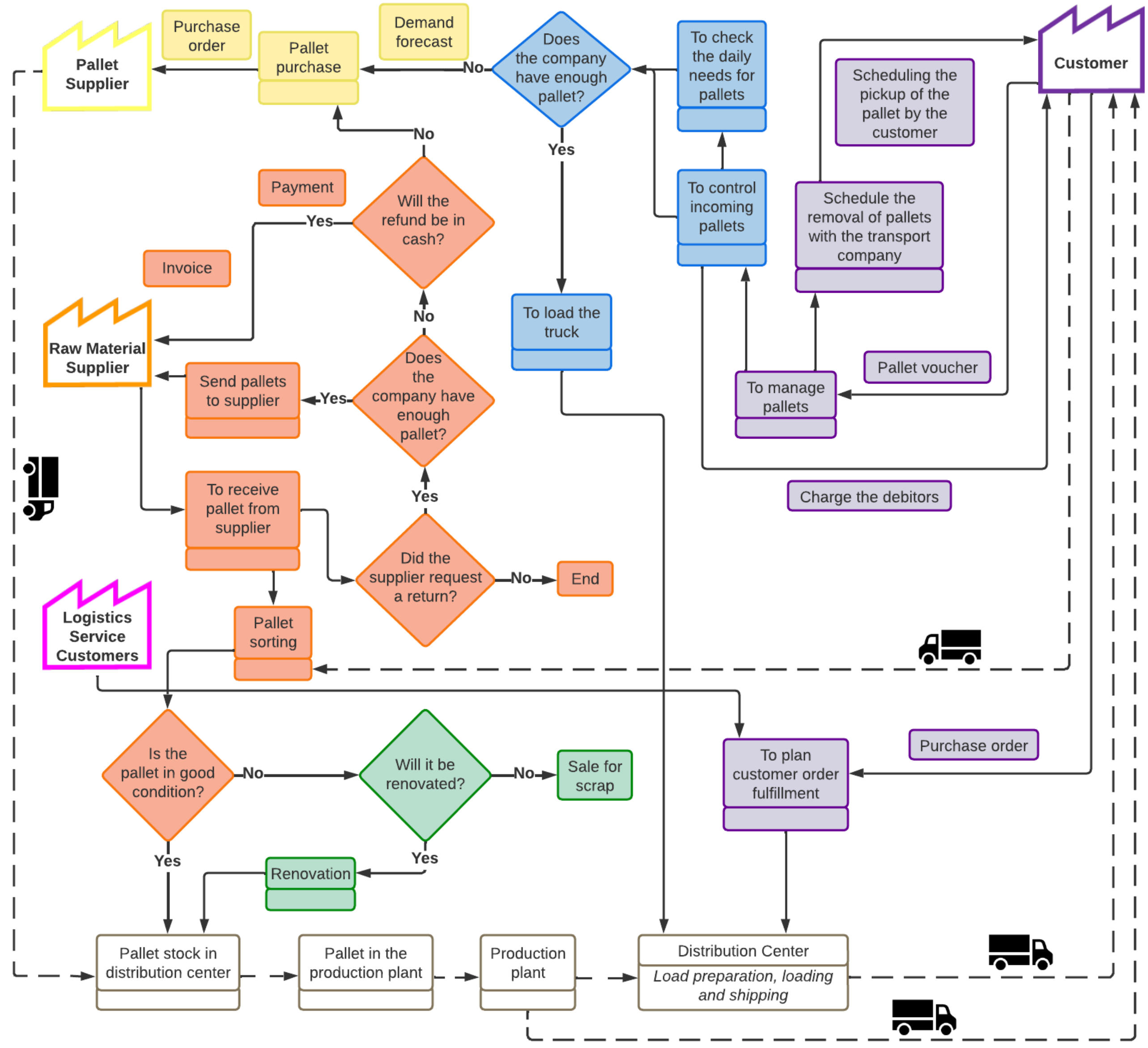

Figure 2. Flow of the pallet management system.

In the final project presentation, it was agreed with the company to continue the project. The objectives for more three semesters were defined, starting with the design of the future value stream map.

From the students' perspective, the main gains observed were the development of both technical and soft skills required by the market. Regarding technical skills, the project allowed students to learn mainly about process standardisation, value stream mapping, and process monitoring. Additionally, students had learned basic concepts about lean manufacturing methodology (Dennis, 2008).

Regarding the soft skills, it was prioritized five skills to develop during the project. Table 2 presents a summary of the main soft skills developed by the students and what moments and actions of the project allowed its development. It was observed that students developed competencies that are often difficult or time-consuming to develop through traditional classroom learning methodologies. In addition, since the beginner of the project the students were instructed about the posture and rules in treating the company's information during the project. As part of this approach, all participants signed a Confidentiality Agreement, emphasizing the importance of acting responsibly and respecting the confidential information involved in the project. This initiative allowed the students to understand and apply ethical principles in their professional activities.

Table 2. Development of soft skills during the Integrative Project.

Key Soft Skills developed	Description of activities/moments/experiences
Teamwork and collaboration	The students were organized in groups and each group received a goal (a process to map). There were students from different semesters of the Production Engineering course who worked together on the integrative project. This experience provided the opportunity for collaboration and mutual learning among the students, strengthening their ability to work as a team.
Communication	There were many moments of interaction with the professionals of the partner company. During the mapping of the flows, the students needed to formulate efficient questions and practise active listening. In the final stage, the students improved their communication skills by presenting the process flows and expressing their ideas clearly and objectively.
Leadership	It was assigned one coordinator to each working group. The coordinators took responsibility for leading their respective groups and integrating the processes between the other groups mapping the interfaces activities, allowing for the enhancement of leadership and team management skills.
Organisation and time management	There was a significant challenge faced by the students concerning the time limitation of the weekly IP meetings, which lasted only one hour. The students, distributed across different semesters and periods (day and night), had to organise themselves and plan efficient strategies to meet the established deadlines, thus developing planning and time management skills.
Systemic vision	The value stream map and the graphical representation of the life cycle were created. Although the process was divided into eight distinct flows, the students worked on integrating these flows and identifying all inputs and outputs of the pallet management system. In this way, the students improved their ability to understand and analyse the system, developing a more comprehensive systemic vision.

During the final project delivery, some students assigned to present did not attend the meeting. The other students demonstrated adaptability and resilience by quickly organizing themselves and taking responsibility for the presentation, ensuring the project was successfully completed despite setbacks. This experience allowed the students to enhance their ability to cope with unforeseen situations and maintain focus on established goals. This experience allowed that in addition to the soft skills previously defined to develop during the project, students could work with skills aimed at adaptability to change e resilience.

The experience of the project was very similar to that presented in the literature, the results of observation of students suggested the project developed students' abilities to share ideas, use multiple representations to present those ideas, and be more receptive to perspectives different than their own (Owens & Hite, 2022).

Some indicators demonstrated the success of the project, such as the low dropout rate of students during the semester, the number of students who decided to continue in the project in the following semester and the maintenance of the partnership with the company for more three semesters.

A limitation of the study was the method of evaluation of the results. The results were evaluated following the model of the integrative projects at the University, that is, evaluating the final report and the presence of the students in most of the meetings. According to Picard et. al (2022), although the most widely used method to evaluate is the final report, presentations and/or products, there are doubts whether this is the best way to evaluate the skills developed.

5 Final Considerations

The objective of this study was to present a case study of an integrative project carried out in partnership between the School of Engineering – Production Engineering course and a large company in the food industry sector to understand how integrative projects are used to develop hard and soft skills in undergraduate students.

The results show that the partnership with the company allows the involvement of students in the solution of real problems, which creates the need for learning. The relationship between the problem and the course disciplines helped to drive the definition of the theoretical content to be taught. In addition, the organization of the way of working could contribute to the development of soft skills.

The project promoted new opportunities for the development of student protagonist through active learning methodologies, as well as empowering students to face new challenges that will contribute to the careers of future engineers.

The collaborative project with a company allowed for engaging students in addressing a real problem, making education more authentic, relevant, and meaningful.

6 References

Athayde, R. R. (2021). A curricularização da extensão e o uso de projetos como meio de colaboração entre universidade e sociedade: caso da Engenharia de Produção da UFRGS [The Curricularisation of Extension and the Use of Projects as a Means of Collaboration between University and Society: A Case Study of the Production Engineering Programme at UFRGS] [Undergraduate thesis, Universidade Federal do Rio Grande do Sul]. Lume. http://hdl.handle.net/10183/235784

Assembleia Legislativa do Estado de São Paulo, Lei nº 16.279. (2016, July 8). Aprova o Plano Estadual de Educação de São Paulo e dá outras providências [Approves the São Paulo State Education Plan and provides other measures]. https://www.al.sp.gov.br/repositorio/legislacao/lei/2016/lei-16279-08.07.2016.html

Bastos, F. (2023, March 21). iFood, Connecting Food e mais 20 empresas se organizam em coalizão para combate à fome [iFood, Connecting Food, and 20 more companies join forces in coalition to fight hunger]. Exame. https://www.exame.com/negocios/ifood-connecting-food-e-mais-20-empresas-se-organizam-em-coalizao-para-combate-fome/

CNE/CES No. 7 (2018, December 18). Estabelece as Diretrizes para a Extensão na Educação Superior Brasileira e regimenta o disposto na Meta 12.7 da Lei nº 13.005/2014, que aprova o Plano Nacional de Educação - PNE 2014-2024 e dá outras providências [Establishes the Guidelines for Extension in Brazilian Higher Education and regulates the provisions in Goal 12.7 of Law No. 13,005/2014, which approves the National Education Plan - PNE 2014-2024 and provides other measures]. Brasil, Ministério da Educação (MEC), Resolução do Conselho Nacional de Educação – Câmara de Educação Superior, Brasília, Brazil 2018. https://normativasconselhos.mec.gov.br/normativa/view/CNE_RES_CNECESN72018.pdf

Dennis, P. (2008). Produção lean simplificada [Simplified lean production]. 2 ed. Porto Alegre: Bookman Editora. 190p.

Duro, M. A. S., Lopes, C. M. C., Casella, E. L., Franzin, R. N. A., Piva, S. S., Vicente, S. A. S., Dourado, R. C. M. M., Rosal, A. C, Leitão, P. J. S., Jr., & Silva, G. R. (2023). Programa triatlo acadêmico: atividades cocurriculares de ensino, pesquisa e extensão [Academic triathlon program: co-curricular activities of teaching, research, and outreach]. Revista Mackenzie de Engenharia e Computação, 22(1), 105-119. http://editorarevistas.mackenzie.br/index.php/rmec/article/view/15047

Freitas, J. P. M. (2022). Gestão de Pessoas e a Engenharia: Contribuições e Formas de Atuação [People Management and Engineering: Contributions and Ways of Engagement] [Undergraduate thesis, Universidade Federal do Pampa]. RIU. https://dspace.unipampa.edu.br/bitstream/riu/7979/1/TCC___Joao_Pedro_Machado_de_Freitas.pdf

IBGE (n.d.), Instituto Brasileiro de Geografia e Estatística. Principais resultados - 4º trimestre 2022 - Distribuição de pessoas desocupadas por idade, 4º trimestre 2022 – https://www.ibge.gov.br/estatisticas/sociais/trabalho/9173-pesquisa-nacional-por-amostrade-domicilios-continua-trimestral.html?t=destaques.

Owens, A. D., & Hite, R. L. (2022). Enhancing student communication competencies in STEM using virtual global collaboration project based learning. Research in Science & Technological Education. 40(1), 76-102. https://doi.org/10.1080/02635143.2020.1778663.

Picard, C. et al. (2022). Which professional skills do students learn in engineering team-based projects?. European Journal of Engineering Education. 47(2), 314-332. https://doi.org/10.1080/03043797.2021.1920890.

Reimers, F.M. (2020). Transforming education to prepare students to invent the future. PSU Research Review, 4(2), 81-91. https://doi.org/10.1108/PRR-03-2020-0010

Rother, M., & Shook, J. (2012). Aprendendo a enxergar: mapeamento do fluxo de valor para agregar valor e eliminar o desperdício [Learning to See: Value Stream Mapping to Add Value and Eliminate Waste]. Lean Enterprise Institute.

Santos, A. B. (2020). A curricularização da extensão universitária a partir do Plano Nacional de Educação do Brasil: dificuldades e possibilidades [The curricularization of university extension from the Brazilian National Education Plan: difficulties and possibilities] [Doctoral dissertation, University of Minho]. RepositóriUM. https://hdl.handle.net/1822/71030

Silva, M. S., & Vasconcelos, S. D. (2006). Extensão universitária e formação profissional: avaliação da experiência das ciências Biológicas na Universidade Federal de Pernambuco [University extension and professional development: assessment of the experience of Biological Sciences at the Federal University of Pernambuco]. Estudos em Avaliação Educacional, 17(33), 119-136. https://doi.org/10.18222/eae173320062130

World Economic Forum. (2023). Future of Jobs Report 2023. Available in: https://www3.weforum.org/docs/WEF_Future_of_Jobs_2023_News_Release_Pt_BR.pdf.

Yin, R. K. Estudo de Caso: Planejamento e métodos. Bookman editora, 2015.

Application of the Initial Phases of the SODA Method In The Production Area of a Chemical Industry

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Abstract

With increasingly uncertain and volatile scenarios, daily problems become ambiguous and complex within companies, which go through adversity on making decisions regarding the interconnection of their employees and internal processes. Increasingly, these decisions about the management of scenarios have become more of a function within the scope of engineers, who leave college with little prepare for these activities guided by soft skills. Thus, the objective is to structure and analyse the socio-technical problems within the production area of the organization in question, identifying their roots and the main issues for improvement, exemplifying the future of engineering job. To achieve this, the initial phases of the Strategic Options Development and Analysis (SODA) method was used to describe the systemic relationships between the problems and their central causes, allowing for a comprehensive view of the area. The main causes identified were the lack of planning and procedures, as well as the fear of the management's reaction. This study provided useful information for the company's leadership to take precise measures to address these issues, improving team interaction and reducing complications in the day-to-day operations of the employees. Additionally, the future work must continue with the SODA method, developing action plans.

Keywords: Strategic Options Development and Analysis (SODA), Problem Mapping, Sociotechnical Problems, Root Causes.

1 Introduction

Operations Research (OR) is a methodology that aims to enhance processes through model construction and optimization techniques, according to Longaray (2013). As a scientific discipline, OR proposes various courses of action, predicts and compares their efficiency and cost values to structure processes. This interdisciplinary field finds application in areas such as production, logistics, and planning, as noted by Arenales et al. (2013).

According to Taha (2007), mathematical modelling forms the foundation of OR. However, intangible and qualitative variables, such as human behaviour, must also be considered when making a final decision. This is where Soft Operations Research comes in, as it deals with complex and ambiguous situations. In any social context, perspectives are relative and plural, depending on the individuals who constitute the given environment, as Yoles (2010) points out.

Soft OR encompasses Problem Structuring Methods, which involve a social learning process that runs parallel to the defined actions instead of relying on abstract data analysis, as per Mingers (2000). These methods contrast with the "traditional" Operational Research by adopting interpretive and constructivist viewpoints and applying them in situations created by diverse individuals, according to Rosenhead and Mingers (2002).

There has been a significant shift in the responsibilities of engineers in the 21st century. According to Fernandes (2015), their traditional role encompassed designing and conducting experiments, analysing situations critically, staying updated with technological innovations, and possessing a solid knowledge base to solve problems and integrate technical-scientific information. However, in the present context, their work has become much more intricate. Increasingly, engineers are taking on managerial roles with transdisciplinary processes, necessitating their involvement in addressing challenges and issues that encompass people and intangible, qualitative variables. Consequently, Problem Structuring Methods prove to be valuable as they provide systematic approaches to identify and resolve impasses encountered by engineers (Wognum, et al., 2019).

The primary aim of this research is to identify potential bottlenecks in the company's production area using the initial phases of the Strategic Options Development and Analysis (SODA) method for problem structuring. The specific objectives of the study are: (i) to conduct a literature review of problem structuring and resolution methods; and (ii) to map and define issues in all relevant areas.

In the uncertain and volatile environments, small problems inside a company can escalate quickly and become very hard to deal with. In such circumstances, businesses must strive to survive against competitors while also maintaining internal stability, therefore, it is crucial to structure the internal problems of the organization and to map and define them from various perspectives present in the organization. Finally, the ramifications of this study are expected to contribute to cost reduction, improved organizational climate, and increased overall company efficiency, provided that the root causes are identified and addressed (Smith & Shaw, 2019).

2 Theoretical Background

Soft Operational Research has gained prominence as Classical Operational Research has come under scrutiny since its methods and methodologies may not be entirely effective in resolving problems that lack a well-defined objective function and mathematically defined constraints. The factors that are relevant to these problems are often unknown, and there is often no agreement on their interrelationships, as emphasized by Arêas (2011). According to Rosenhead (2006), the problems that Soft Operational Research aims to solve are characterized by multiple actors, diverse perspectives, partially conflicting interests, significant intangibles, and perplexing uncertainties.

Problem Structuring Methods (PSM) typically address problems referred to as "messes", which are characterized by plural perspectives and goals among stakeholders. Ackoff (1979) notes that these problems exist in dynamic environments and complex systems where they interact with each other. Churchman (1967) adds that these problems cannot be entirely formulated, lack fixed constraints, cannot be classified as true or false, and cannot be immediately or definitively tested, and each problem is unique. Georgiou (2010) highlights the importance of the Strategic Options Development and Analysis (SODA) method in Soft Operations Research, particularly in group decision-making situations with complex and uncertain problems that cannot be modelled by algorithms.

The cognitive mapping is the main tool used in SODA, which provides a clear and transparent interface for making better decisions and improving problematic situations within their context. Cognitive Maps, as described by Eden and Ackermann (2001), depict problem-solving through node and link networks, where arrows indicate causality. The information is derived from interviews or document analyses and must be constructed to eliminate any ambiguities in the problem situation. By combining cognitive maps, the SODA Map is constructed based on the psychological constructs theory presented by Kelly (1995). The psychological constructs bring the informal knowledge of each participant to the map, eliminating ambiguities and contradictions by presenting opposite poles that aim to clarify the context under study. After defining each construct, links are created to indicate causality and reveal possible hierarchical relationships in the SODA Map, distinguishing it from the cognitive map.

3 Characterization of the Company Under Study

The subject of this study is a company that was founded in the 1980s by a father and son who had expertise in chemical compounds related to the production and handling of rubber products. At first, the company's services were limited to distributing certain chemical products, but it gradually started developing and manufacturing its own products in-house for commercial purposes. Furthermore, the company actively engages in intermediation activities between large producers and small-scale retailers. For instance, it produces, resells and distributes products sourced from big companies by procuring large volumes of oil and dividing them into smaller containers for distribution to smaller producers. Ultimately, the company distributes its products all over Brazil, utilizing its own fleet and external distributors.

4 Method

This study is of an applied nature, as it tests theories in a real-world setting and seeks to understand the perspectives of respondents in a specific field (Flick, 2013). Due to the lack of related studies, the research takes on an exploratory character (Collado, Lucio & Sampieri, 2013) and the variables are qualitative. The data are descriptive in nature, providing a detailed description of a phenomenon or situation, as well as describing the relationships between the studied parts (Selltiz et al., 1965). The research scope is characterized as a case study, which aims to analyse a phenomenon in its real context to gain in-depth knowledge and elaborate on questions, hypotheses, and/or solutions for the identified problems (Miguel, 2007).

To collect the necessary data, the research team decided to conduct interviews with key employees from the Production department using the SODA method. A questionnaire validated by the Ethics Committee was used for individual interviews with all respondents to capture their vision of the company's scenario and identify any problem areas. The questionnaire (Marques, et al., 2021) comprised open-ended questions, which focused on understanding the employee's trajectory within the organization, the activities performed, and past situations to identify possible adversities.

The collected data were organized in the second phase of the study using the SODA Problem Structuring Method. This approach was used to identify and structure subjective and ambiguous problems that could not be analysed quantitatively. The main tool for this method was the creation of cognitive maps, which captured information about a specific topic through the perception of the individuals involved.

The interviews were conducted in a private environment to ensure data security and confidentiality, and the authors introduced themselves and explained the purpose of the study, its objectives, and provided a Confidentiality Term. The questions were conducted impartially and strategically, and the interviewees' speeches were transcribed by another author. Topics such as organizational climate, leadership, teamwork, problem-solving, power relations, skills, lifestyle, and expectations were addressed.

The developed cognitive map will be used as a consensus tool for the interviewed group and represents the commitment to the proposed solutions. Additionally, the map will be used to structure the root problem and analyse the data obtained through the transcription of the interviews or the files made available. The SODA method requires special attention to language, which is fundamental for the composition of the main ideas of the cognitive map.

5 Results

Effective problem-solving requires identifying the root causes of the issue at hand. This allows for the development of targeted and effective solutions that address the problem at its source. To achieve this, it is necessary to gather and analyse information from various sources and perspectives, considering the complexity of the situation and interpersonal dynamics (Manso et al., 2015). The SODA method, used in this study, is a valuable tool for exploring multiple perspectives and uncovering abstract and individual factors that contribute to the problem. By creating individual cognitive maps and conducting a causality analysis, the study aims to identify the root causes of the problem and ensure that social and relational factors are considered in the analysis.

5.1 Map A - Production Leader 1

Map A, depicted in Figure 1, was constructed based on an interview conducted with a production leader who had three years of experience in the organization and was exposed to the chemical area and production sector for the first time. The information gathered from this interview provided a comprehensive understanding of the primary factors that contribute to the problem being studied.

Upon analysis of Map A, it is evident that there are various interrelated constructs. For instance, construct A1 serves as a root cause for constructs A2 and A4, which pertain to new employees concealing mistakes. This behaviour can be attributed to inadequate training and lack of experience in the field, as indicated by construct A3. Additionally, construct A5 indicates the intersection between the topics of turnover and leadership, which can be traced back to issues with management training. Other constructs in the map relate to employee turnover, which is often caused by the absence of career development opportunities within the organization (A13 and A11). Notably, machinery-related issues are also highlighted in the map, emphasizing the need for predictive and preventive maintenance planning (A10, A12, and A14). Conversely, topics such as conflicts between departments (A8) and the physical layout of the factory (A9) seem to have no apparent connection with the other nodes.

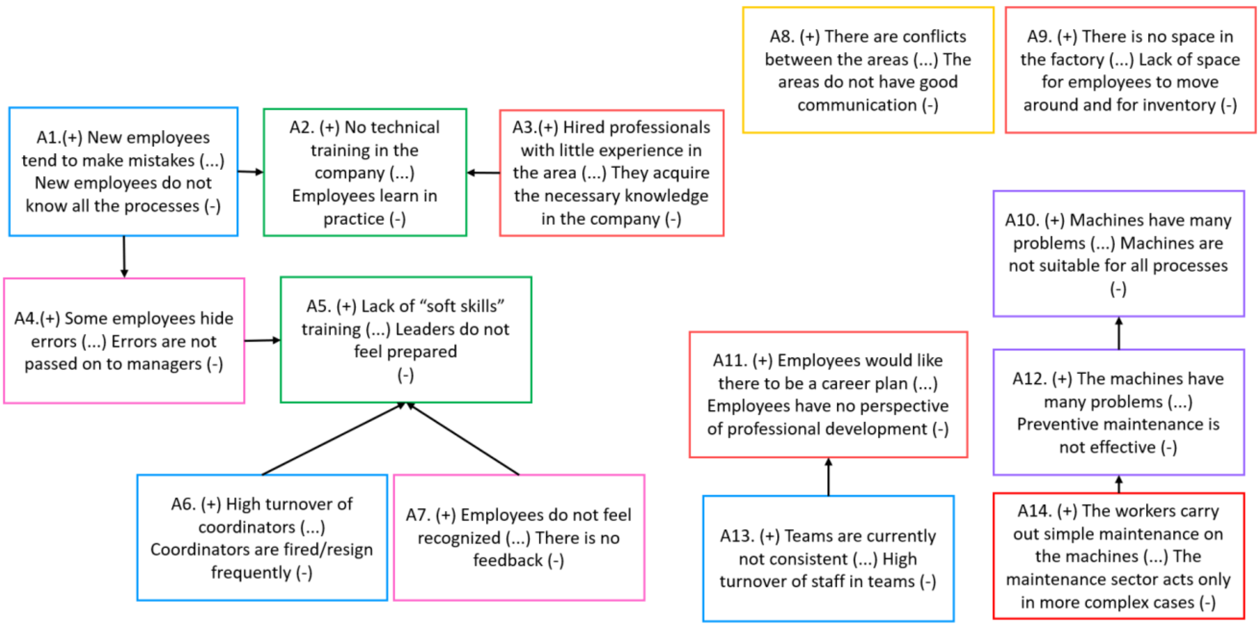

Figure 1. Map A – Production Leader 1 Cognitive Map.

5.2 Map B – Machine Operator

Map B (Figure 2) was created based on an interview with a machine operator who has been with the organization for 30 years and has worked in various roles, including caretaker, gardener, logistics operator, and forklift operator.

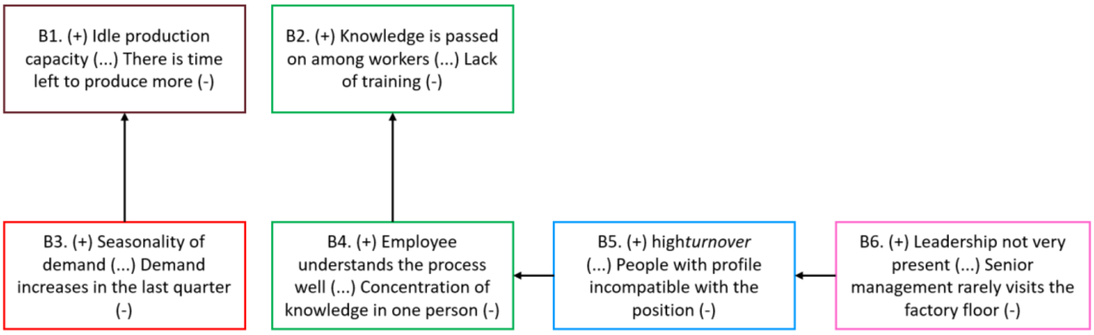

Figure 2. Map B – Machine Operator Cognitive Map.

The first construct analysed in Map B is B4, which shows a cause-and-effect relationship with constructs B2 and B5. This construct highlights the concentration of knowledge about the production process, which is related to high turnover, lack of structured training by the company, and dependence on one person to perform certain tasks. This is also related to the low presence of leadership on the factory floor (B6), which affects their understanding of processes. Furthermore, Map B also addresses aspects related to the seasonality of demand (B3) and the idle capacity of the factory (B1) as challenges in balancing workload and capacity during certain periods.

5.3 Map C – Production Leader 2

Map C (Figure 3) was generated from an interview with the second production leader, who has been with the company for 2 years and has experience in the chemical industry, previously working in logistics before moving to production.

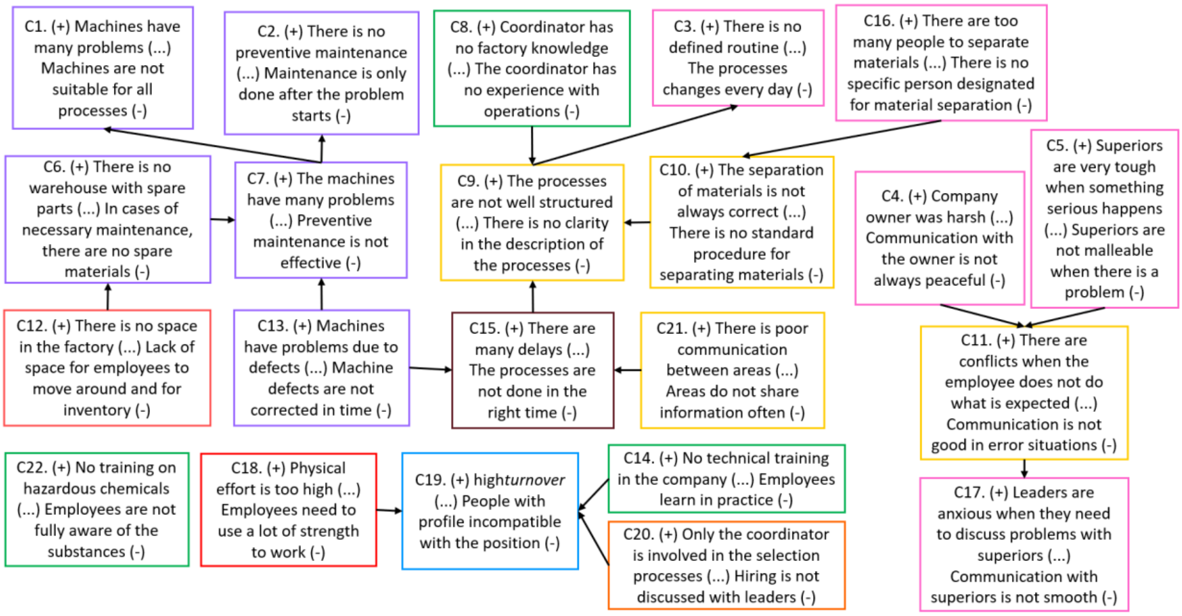

Figure 3. Map C – Production Leader 2 Cognitive Map.

The C7 construct is a strategic option within the map, with several constructs related to it. The lack of preventive maintenance (C2), the use of machines for unintended purposes (C1), and defects resulting from insufficient maintenance materials and space (C12, C6, C12) all accompany problems with the machines. Another important construct is C9, with several nodes related to it. The lack of process structuring leads to a lack of routine (C3), which is caused by the coordinator's inadequate knowledge (C8), delays, lack of communication between departments, and mistakes in material separation (C15, C21, C13, and C10). Three constructs related to leadership (C4, C5, and C17) and one related to communication (C11) are related to employee errors and strict punishments from superiors. As in the previous map, high turnover rates (C19) are caused by overload (C18), insufficient training (C14), and coordinators' lack of involvement in the selection process (C20).

5.4 Map D – Forklift Operator

Map D (Figure 4) was based on an interview with a forklift operator who had only been with the company for 3 months, despite prior experience in the industry.

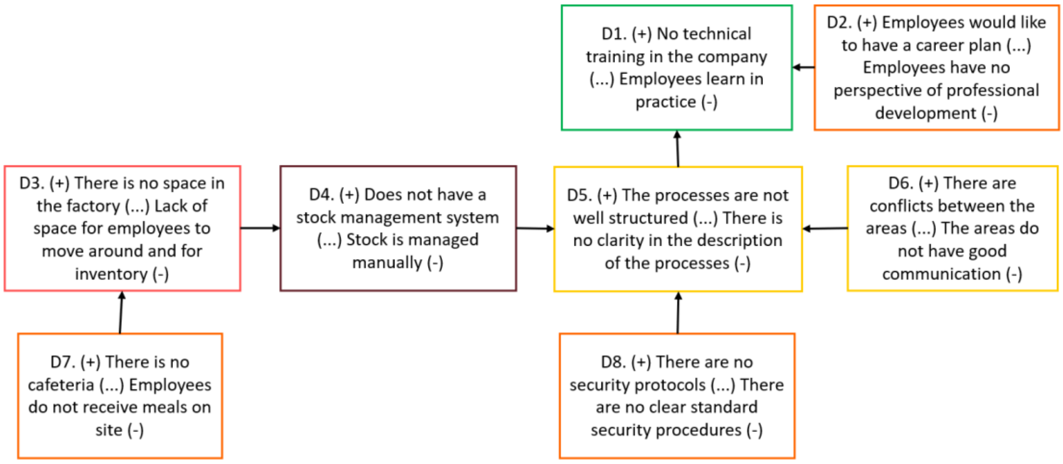

Figure 4. Map D – Forklift Operator Cognitive Map.

The most significant construct in Map D is D5, which encompasses the lack of structured processes, with all other constructs directly or indirectly related to it. Constructs with a causal relationship leading to D5 include the lack of inventory management (D4), insufficient physical space (D3), non-existent security protocols (D8), and conflicts between different departments (D6). Furthermore, construct D1 highlights the lack of training provided by the company, which leads to the consequence of D5.

5.5 Map E – Production Assistant

Starting with Map E (Figure 5), it was based on an interview with one of the production assistants who had about 1 year of experience in the organization at the time of the interview, but had already worked as a production assistant in other industries.

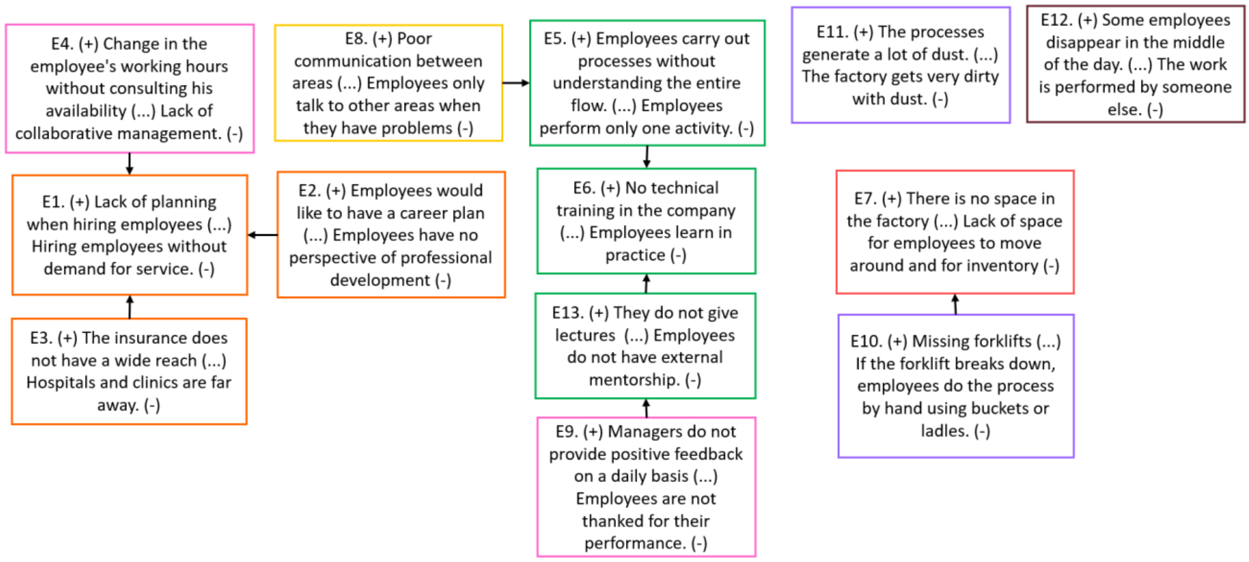

Figure 5. Map E – Forklift Operator Cognitive Map.

The most significant construct in Map E is E1, which has a strong consequence relationship with the constructs E2, E3, and E4. It shows the link between the lack of professional development perspective, the lack of collaborative management of resources, and the lack of planning in the hiring of employees. Furthermore, the E6 construct has an effect relationship with the other constructs. It is about technical training, and it is related to the lack of communication both between areas (E8) and within them (E5), as well as the lack of management by coordinators and managers (E9 and E13). Finally, constructs E7, E10, E11, and E12 are further away from the others but still highlight the lack of physical space, as well as the lack of cleanliness, machinery, and overload among employees.

5.6 Map F – Production Coordinator

Figure 6, or Map F, was constructed following an interview with the production coordinator, who possesses both a degree and a master's degree in Engineering and has been with the organization for approximately six months. The coordinator also has prior experience in the industry and people management. The Map F incorporates the F18 construct as a strategic option, given its numerous interconnected nodes, which all have a consequential impact on the covered topics. The construct's focus lies in the organizational climate, specifically concerning leadership themes (F14, F17, F19, F20), and HR recognition (F21). Another construct of note is the F7, which is also intertwined with other items and primarily addresses the lack of planning and management of processes. Communication-related constructs (F6, F8, F10, F11) are mainly concerned with the inadequate speed of information flow, which stems from the lack of process ownership (F16) and difficulty accessing administrative information (F15).

Similarly, to the previous map, the lack of physical space (F1) is also linked to issues of cleanliness (F1) and inventory management (F6). Additionally, errors in production and the subsequent treatment of operators and managers (F4, F5, F9, F13, F14) are significant concerns.

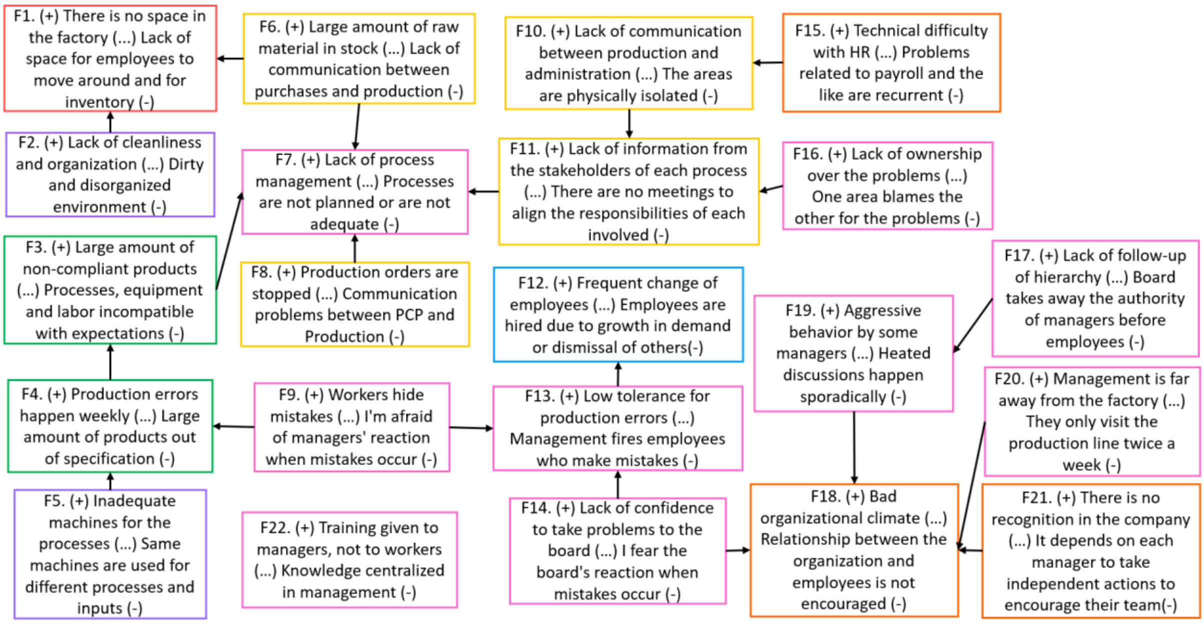

Figure 6. Map F – Production Coordinator Cognitive Map.

6 Discussions

Upon completion of the interviews and individual cognitive map preparation, the identified constructs were organized into nine main themes that emerged from the research: communication, physical space, leadership, machinery/maintenance, human resources, overload, training, turnover, and others, as depicted in Table 1. This classification facilitated the identification of the most prevalent issues discussed, serving as a framework for developing targeted actions to address the raised concerns.

Table 1. Construct classification by theme

Subject	Constructs
Communication	A8; C9; C10; C11; C21; D5; D6; E8; F6; F8; F10; F11
Space	A9; C12; D3; E7; F1
Leadership	A4; A7; B6; C3; C4; C5; C16; C17; E4; E9; F7; F9. F13; F14; F16; F17; F19; F20; F22
Machines	A10; A12; C2; C6; C7; C10; C13; E10; E11; F2; F5
Human Resources	A3; A11; C20; D2; D7; D8; E1; E2; E3; F18; F21
Overload	A14; B3; C18
Training	A2; A5; B2; B4; C8; C14; C22; D1; E5; E6; E13; F3; F4
Turnover	A1; A6; A13; B5; C19. F12
Others	B1; C15; D4; E12

Interpretation of the maps revealed multiple concerns, including inadequate training, insufficient physical space in the factory, deficient production planning, and inadequate safety protocols and standard operating procedures. Nevertheless, the most critical issue to address is the lack of trust employees have in the board, indicating an inadequate organizational climate for communication. This leads to a repressive culture and concealment of errors, both by managers and production leaders, as well as workers, impeding the search for solutions and alternatives to problems.

7 Conclusion

The present study successfully achieved its initial objective of identifying possible barriers within the production area of the chosen company, determining their root causes, and highlighting key areas for improvement. The lack of planning and procedures, as well as fear of management's reaction to errors made by workers, were identified as the primary causes.

The application of the SODA method proved to be an effective approach for studying sociotechnical problems, offering a flexible approach to describing the systemic relationships between problems and their central causes. Even with only the Cognitive Maps, the relationship between the comments transformed into constructs was essential for gaining a holistic understanding of the production department's internal and external relationships. The maps provided evidence of the main adversities and their root causes, enabling more precise decision-making to reduce expenses, improve the organizational climate, and increase the company's efficiency overall. The study's insights will indirectly benefit the participants of the interviews, as they will inform the leadership's actions in resolving these problems, ensuring better team interaction and less complications in employees' daily lives.

It is essential to continue studying and applying the SODA method in future works, beginning with the second stage where the maps are integrated for a systemic analysis, building a single map that aggregates similar constructs and creates new relationships between nodes. Analysing this map will result in a more comprehensive guideline for constructing action plans based on the insights presented.

Still, it becomes evident that there is a need for a greater focus on soft skills during the academic development of professionals, given that these skills permeate professional relationships and, therefore, positively or negatively interfere with the success of the company or any decision-making.

8 References

Ackoff, R. L. (1979). The Future of Operational Research is Past. The *Journal of the Operational Research Society, 30*(2), 93-104. https://doi.org/10.2307/3009290

Arêas, D. B. (2011). Métodos de Estruturação de Problemas e a Extensão Universitária. [Doctoral dissertation, Universidade Federal do Rio de Janeiro]. Catálogo: Base Minerva. http://objdig.ufrj.br/60/teses/coppe_d/DanielBragaAreas.pdf

Arenales, M., Armenato, V., Morabito, R., & Yanasse, H. (2013). *Pesquisa Operacional*. [Operational Research]. Elsevier.

Churchman, C. W. (1967). Guest Editorial: Wicked Problems. *Management Science, 14*(4), B141–B142. http://www.jstor.org/stable/2628678

Collado, C. F., Lucio, M. Del P. B., & Sampieri, R. H. (2013). *Metodologia de pesquisa* [Research Methodology]. Penso.

Eden, C., & Ackermann, F. (2001). SODA - the principles. In J. Rosenhead, J. Mingers (Ed.), *Rational analysis for a problematic world revisited* (2nd ed., pp. 21-41). Chichester, Wiley Press.

Flick, U. (2013). *Introdução à metodologia de pesquisa* [Introduction to research methodology]. Penso.

Georgiou, I. (2010). Cognitive Mapping and Strategic Options Development and Analysis (SODA). J. J. Cochran (Ed.), *Wiley Encyclopedia of Operations Research and Management Science* (pp. 1-10). John Wiley & Sons.

Kelly, G. A. (1995). *Psychology of personal constructs: a theory of personality*. Norton.

Longaray, A. A. (2013). *Introdução à Pesquisa Operacional*. [Introduction to Operations Research]. Saraiva, 2013.

Manso, D. F., Suterio, R., & Belderrain, M. C. N. (2015). Mapping out Sao Paulo state's disaster management system through the SODA method. *Gestão & Produção*, 22(1), 4-16. http://dx.doi.org/10.1590/0104-530X1105-13

Marques, B. D., Silva, C. P., Gimiliani, S. S., & Carvalhal, M. A. (2021). Interview - Application of the Initial Phases of the SODA Method In The Production Area of a Chemical Industry Interview Script. http://dx.doi.org/10.13140/RG.2.2.35444.53125

Miguel, P. A. C. (2007). Estudo de caso na engenharia de produção: estruturação e recomendações para sua condução. *Production, 17*(1), 216–229. https://doi.org/10.1590/S0103-65132007000100015

Mingers, J. (2000). Variety is the spice of life: combining soft and hard OR/MS methods. *International Transactions in Operational Research, 7*(6), 673-691. https://doi.org/https://doi.org/10.1111/j.1475-3995.2000.tb00224.x

Rosenhead, J. (2006). Past, present and future of problem structuring methods. Journal of the Operational Research Society, London, v. 57, n. 7, p. 759-765, 1 fev. 2006.

Rosenhead, J., & Mingers, J. (2002). Problem structuring methods in action. *European Journal of Operational Research, 152*(3), 530-554. https://doi.org/https://doi.org/10.1016/S0377-2217(03)00056-0

Selltiz, C., Wrightsman, L. S., & Cook, S. W. (1965). *Métodos de pesquisa das relações sociais*. [Social relations research methods]. Herder.

Smith, C. M. & Shaw, D. (2019). The characteristics of problem structuring methods: A literature review. *European Journal of Operational Research, 274*(2), 403-416. https://doi.org/https://doi.org/10.1016/j.ejor.2018.05.003

Taha, H. (2007). *Operations Research: An Introduction*. Pearson.

Wognum, N. et al. (2019). Transdisciplinary systems engineering: implications, challenges and research agenda. International Journal of Agile Systems and Management, v. 12, n. 1, p. 58-89. https://doi.org/10.1504/IJASM.2019.098728

Yoles, M. (2010). Exploring Complex Sociocultural Situations Through Soft Operational Research. Pesquisa Operacional, 30(2), 345–370. https://doi.org/10.1590/S0101-74382010000200006

A proposal for teaching and learning of Quality Management Discipline using the TPACK (Technological Pedagogical Content Knowledge Framework) model.

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Abstract

The effective integration of digital technologies in the teaching and learning process depends, besides to knowledge of their content, on education professionals having other skills that will lead them to make the best use of these technologies in teaching, in accordance with their pedagogical objectives. In this way, this article aims to describe the construction of a proposal, the contributions and challenges from the teacher's point of view, from the integration of educational technologies and active methodologies to the planning of the discipline "Quality Management", specifically in the "Flowchart" content, from the class of the 1st module of technical education concurrent with High School in Logistics, from a federal public educational institution. The intervention proposal, using the TPACK model (Technological Pedagogical Content Knowledge Framework), was developed by the institution's Nucleus of Educational Technologies (NTE), formed by servants of the education area, in partnership with the subject's teacher. The work was developed in the context of the actions proposed by the NTE for 2023. Among the contributions, the reduction of correction work and greater focus on planning, change in the teacher's perception about the potential of conducting the contents and the direct relationship of the choices with the context in which the discipline is inserted; the challenges for the development of the proposal were centred on resistance to changes, due to the teacher's little knowledge and experience in relation to educational technologies and active methodologies. The expectation of this article is that, with the presentation of the proposal and the reflections about the potential of the TPACK model, it will be possible to encourage other teaching professionals to consider technologies and active methodologies in the development of the planning of their disciplines, given the importance and contribution of the theme for constant improvement of the teaching-learning process and dropout reduction.

Keywords: Active Learning; Technology Education; TPACK; Quality Management.

1 Introduction

Quality Management is one of the academic disciplines that compounds the Pedagogical Project of the Logistics technical course at the Federal Institute of Espírito Santo (Ifes) *campus* Cariacica, as well as other technical and undergraduate courses (Gonçalves & Pereira, 2016). The Quality Management discipline presents some objectives that must be developed throughout the course, being some of them (a) identifying the main influential factors in the quality management of products and services looking for excellence; (b) understanding and analyzing the main quality management and assurance processes; and (c) applying quality management concepts in a result-oriented environment.

This discipline presents, in its syllabus, the topic "Flowchart" that proposes, for its construction, the development of a logical reasoning of the student.

The logical reasoning required by the Quality Management discipline, which is also essential in other subjects, interferes with student learning and is not always properly presented to the student knowledge background (Barcelos *et al.*, 2009). What increases students' enthusiasm and promotes more effective learning is the use of technological resources (Braga & Yada, 2021; Barcelos *et al*., 2009). Within the context of quality management, making use of new technologies, or digital information and communication technologies, is considered essential for the quality of products and services (Braga & Yada, 2021).

The use of digital technologies in the teaching-learning process enhances and expands the range of possibilities for teaching certain contents or using different methodologies. However, for its use to be maximized, it is crucial that such integration occurs linked to a specific pedagogical strategy, for working a certain topic.

The theoretical framework that takes into account the articulation between these categories of knowledge is known as the TPACK approach (Technological Pedagogical Content Knowledge).

TPACK was developed by Mishra and Koehler (2006) as the necessary knowledge that teachers need to integrate technology into their teaching (Goulart *et al*., 2018; Sampaio & Coutinho, 2014). The TPACK approach was developed from Shulman's Pedagogical Content Knowledge (PCK) (1986, 1987). The PCK represents the essential knowledge that a teacher needs to teach and be a good teacher. For Shulman (1987), PCK is that amalgam between content and pedagogy belonging solely to the universe of teachers.

PCK is not just the intersection of pedagogical and content knowledge. It means knowing pedagogical strategies and knowing how to use them to adequately present certain content. Mishra and Koehler (2006) add technological knowledge to this construct, thus obtaining pedagogical technological content knowledge. TPACK represents the articulation between content, technology and pedagogy and the complex connections between this knowledge and the context (Sampaio & Coutinho, 2014).

Therefore, integrating technology in teaching requires an understanding between these different categories of knowledge (Sampaio, Coutinho, 2014). This framework presents the relationships between knowledge in isolation as well as the relationship among peers: pedagogical content knowledge (PCK), technological content knowledge (TCK), pedagogical technological knowledge (TPK) and the three together as technological pedagogical knowledge of the content (TPACK).

TPACK is much more than the three isolated areas of knowledge: content, technology and pedagogy. In order to teach effectively using technology, it is essential to develop a comprehensive understanding of the subject in relation to technology and what it means to teach with technology (Niess, 2005).

Therefore, this work aims to understand the connections between these different categories of knowledge, looking for articulating them to contribute to the understanding of the Flowchart theme in the Quality Management discipline of the technical course in Logistics.

2 Methodology

This article describes a proposal for pedagogical intervention. It is considered qualitative research, due to the need to deal with information directly from the perceptions of direct participants during the data collection process, in order to obtain a deeper knowledge about the studied subject. After a brief literature review, described in the introduction, the work was divided into two stages: the description of the context and research object and the description of the intervention proposal itself.

2.1 Stage 1 - Context and Research Object

The research presented here was conducted in a federal public school, with a teacher who teaches the subject of Quality Management in classes of first year of technical courses integrated with high school education and in classes of first semester in technical courses concomitant with high school education. The specific content worked with the teacher was "Flowchart", taught in the year 2023, for 33 students of the concomitant technical course in Logistics.

The Quality Management subject aims to help students understand the principles, concepts, methods and tools adopted in quality management used in logistics companies.

2.1.1 Methodology for Developing the Flowchart Content

The "Flowchart" topic fits into the specific objectives of the subject: "to know and to use the main tools for control and evaluation of the quality of services, products and processes" and "to know and to map processes." This content has a workload of 5 hours, to be worked in 6 classes of 50 minutes each.

Currently, the teacher uses Moodle as the virtual learning environment to manage her subject, as well as to work on her content, such as theoretical contents, exercises, and other activities. In the physical classroom, the teacher has access to multimedia projectors, materials with content in presentation software, and the Moodle platform. Her methodology includes expository-dialogue classes and exercises. In order to assess the content, the teacher apply written exams and exercises.

The Flowchart content is evaluated in a written, individual, and non-consultative exam, usually along with the following contents: Brainstorming, GUT Matrix, and Checklist. In addition to this evaluation, some exercises are carried out during the classes. This dynamic can be seen in Table 1:

Table 1. Current Methodology.

Classes	Item	Specific Contents
Class 1	Expository class	Flowchart: Structure, Objectives, Advantages, Analysis and Symbols
Class 2	Expository class	Flowchart Types
Class 3	Expository class	Guidelines for creating a flowchart
Class 4	Individual Writing Task	The process description is informed to the students and they must create the correspondent flowchart. In this task, it is evaluated, mainly, if the student knows how to draw the tool structure (Figure 1).
Class 5	Individual Writing Task	The context of an institution's operation and a general description are informed to the students, and they must create the correspondent flowchart. In this task, the analysis of the problem, the student's ability to understand the flowchart concept, its objectives, and the student's ability to build the sequence of steps necessary for detailing the process are evaluated (Figure 2).
Class 6	Test	The Flowchart content is evaluated in a written test, individual and without additional material, in which students are tested on the following aspects of the content: Structure, Objectives, Advantages, Analysis, Symbols, Flowchart Types, and Flowchart Construction.

2.1.2 Difficulties encountered in learning Flowchart

The teacher's initial report was that the students found it difficult to develop the flowchart, based on a specified problem. In later conversations, the professional stated that the students' difficulty was not in understanding the objectives and functions of the flowchart, nor in discerning between the elements necessary for its construction. On the other hand, the teacher understands that the real need of the students is in the analysis stage, i.e. in understanding the problem, developing logical reasoning and transforming this understanding into a flowchart.

2.2 Stage 2 - Pedagogical Intervention Proposal - Didactic Sequence

After interviewing the subject teacher and analyzing the evaluations of the last semesters, the Nucleus of Educational Technologies (NTE), together with the teacher, elaborated a didactic sequence – using TPACK model as theoretical framework (Table 2) – in order to teach the "Flowchart" content with new strategies, integrating active methodologies and digital technologies to her regular classes.

Table 2. Didactic Sequence

Discipline	Quality Management
Time	300 minutes
Nº of students	Class: LOG 1A Nº of students: 33
Learning Methodology	Active Learning
Technologies	Educational Game and Collaborative Software
Content	Flowchart
Objective	Enable students to know how to analyze a logical problem. Enable the student to understand the concept of flowchart, its objectives, and help the student to build the sequence of steps necessary for detailing the process.
Work methodology	**Day 1 - Concepts and understanding of the functionality of a flowchart.** Class objective: Interpret and develop simple flowcharts, identifying the relationships between the represented objects. Understand the importance of the flowchart in the most varied contexts, especially in the context of the course. Resources: Multimedia projector, computer and paper. **Part 1 - Logic** ● Objective: At the end of this stage, students should be able to interpret a simple flowchart, although they have not yet been introduced to flowchart concepts. ● Task 1: ○ Define a simple process that contains **sequential** steps that students are able to perform in class. E.g., Origami. ○ Show the Flowchart ready to carry out this process. ○ Students must follow the steps of the flowchart and finish the process; at the end, they show the result. ● Task 2: ○ Define a simple process, with steps that contain **decision making**, and that students are able to execute.

- Show the Flowchart ready to carry out this process.
- Students must follow the steps of the flowchart and finish the process; at the end, they show the result.

- Discussion about the activities carried out: Each student must show their results and compare with the others and with the teacher, to verify if they concluded successfully and analyze the results.
- Teacher's feedback, contextualizing the need to use the flowchart and its contributions to the logistics area.

Part 2 - Expository Class

- Objective: To introduce the concepts of Flowchart, its Structure, its symbols and its types.

Day 2 - Educational Game

Class Objective: Understand the construction of a flowchart and the importance of its correctness for quality management.

Resources: educational game, multimedia projector, computer.

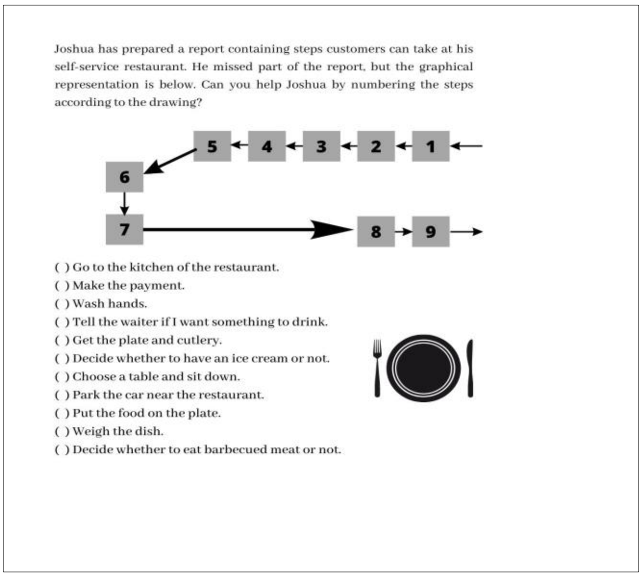
Part 1 - Expository Class

- Objective: Guidelines for building a flowchart.

Part 2 - Practice using Educational Game

Class Objective: Learn in practice the logical structure of drawing up a flowchart.

- Task: Practical task using an educational game (pedagogical object built by the team)
  - Example of task to be carried out using the educational game:



Joshua has prepared a report containing steps customers can take at his self-service restaurant. He missed part of the report, but the graphical representation is below. Can you help Joshua by numbering the steps according to the drawing?

( ) Go to the kitchen of the restaurant.
( ) Make the payment.
( ) Wash hands.
( ) Tell the waiter if I want something to drink.
( ) Get the plate and cutlery.
( ) Decide whether to have an ice cream or not.
( ) Choose a table and sit down.
( ) Park the car near the restaurant.
( ) Put the food on the plate.
( ) Weigh the dish.
( ) Decide whether to eat barbecued meat or not.

	After completing the task, the teacher will give constructive feedback on what has been accomplished.
	Day 3 - Collaborative Tool Objective: Assemble a flowchart collaboratively. Resources: "Miro" software as a collaborative tool, paper, pencil and computer. **Practice using collaborative tool.** Task: 1) In the computer laboratory, introduce the Miro tool to the students; 2) Divide students into 7 groups of 4 people and 1 group of 5 people; 3) Deliver objects to 4 groups that will be used for them to draw an object; 4) These 4 groups must build their object through a drawing; 5) In Miro software, the students in these 4 groups must build the flowchart referring to the construction of the given object; 6) When the first 4 groups are finished, the other 4 groups receive the same elements and the flowchart, and they must then draw the object following the flowchart; 7) Then switch groups and repeat the process. Teacher feedback: importance of good flowchart design for quality in the development of products and processes.
Evaluation	The evaluation will be measured qualitatively, valuing participation in discussions and commitment to activities.

3 Results and Discussion

The development of the Didactic Sequence using the TPACK model considers knowledge related to the content of the discipline, areas of the teaching process and the optimized use of technological resources, as well as the intersection of this knowledge. In this way, teachers are trained to plan interventions using pedagogical strategies and appropriate technologies to facilitate student understanding, taking into account their experiences and skills developed throughout their careers.

During the intervention planning, weaknesses in the content that occurred in the traditional approach were verified. Thus, leaving the teacher's comfort zone, a proposal was reached that advocates active learning with the use of educational technologies in order to resolve students' difficulties with the analyzed content, seen in previous semesters. In addition, another advantage noted by the teacher is linked to the fact of optimizing the time dedicated to the content, as the proposed activities contemplate the subject in a dynamic way and directed to the most relevant points.

The main challenge encountered during the intervention was to adapt the teacher's teaching methodology in order to insert teaching in a technological and more contemporaneous context. In addition, the teacher's concern with the development time of the content in the teaching plan was also an obstacle to overcome. However, the history of performance and assimilation of the content by previous classes came up, leading the teacher to conclude that it was time to insert a new pedagogical strategy. In this scenario, the NTE showed to the teacher the potential that exists in the use of technologies and active methodologies in the content under analysis, which culminated in the collaborative elaboration of the presented didactic sequence.

At the end of the preparation of the pedagogical intervention proposal, a process of transformation was observed in the teacher, when she came to understand and managed to include, in this pedagogical practice, the main and most important elements in relation to the content of the "Flowchart", using active methodologies. In the teacher's perception, this paradigm shift allowed an expanded view of this and other contents, thus highlighting the change in perception about the potential of conducting the contents and the direct relationship of the choices with the context in which the discipline is inserted. It is known that the most difficult change to be assimilated is the awareness that part of the content is sufficient to solve certain problems and that other parts may not be addressed (Silva, 2020). Therefore, we understand that for active methodologies to be effective, teachers need to be prepared to change their conceptions of teaching and learning, opening up new forms of interaction with knowledge and innovative solutions for activities.

Still, it is worth noting that, during the development of the proposal, it became clear that to learn to develop or understand a flowchart, it is necessary to understand the logic of the process, and this factor is a weak point for most students: computational thinking. It was understood that mastery of logical reasoning is necessary for learning this and other disciplines. However, it is a knowledge that students should have previously acquired, because it takes time to learn it. In order to minimize losses, the following proposals were defined: (1) the inclusion of programming logic content in the informatics discipline, at the beginning of the school semester, with the aim of developing computational thinking, using Scratch software, and changing the presentation date of the Flowchart content. Despite the understanding of the Informatics teacher about the inclusion of programming logic content in the Applied Informatics discipline, it is understood that including the content in the teaching plan is important for continuity, regardless of who the teacher is. This change in the Informatics Teaching Plan is in progress, as the course is currently undergoing a restructure of its Pedagogical Project. For this end, one of the specific objectives of the Applied Informatics discipline will be "Developing computational thinking"; (2) the teaching plan for the subject of Applied Informatics will keep the specific objective of: knowing how to apply and use information systems applied to the area of Logistics, which will contribute to the learning of computational tools, such as the Miro software, for the elaboration of flowcharts.

4 Final Considerations

We consider that the study in question achieved the research objectives. In a collaborative way (NTE and teacher), a didactic sequence was set up for the content "Flowchart" of the discipline "Quality Management", having as a theoretical framework, the TPACK model, Active Learning Methodologies and Educational Technologies.

With the collaborative elaboration of the didactic sequence, the teacher was aware about the potential of the TPACK model and the importance of considering it as a tool in her pedagogical practices. Furthermore, during the elaboration of the proposal, the NTE team identified lack of knowledge and resistance from the *campus* teaching team towards the use of technologies applied to education. In addition, the need for computational thinking was perceived, considering the development of logical reasoning as a fundamental requirement for the future professionals (Barcelos *et al.*, 2009). In this sense, the NTE at Ifes *campus* Cariacica will expand training for the teaching staff (administrative technicians and teachers) in order to demystify and clarify the use of technology in the school daily life. This work is necessary due to the rapid technological advances in recent years, including software aimed at active learning, Industry 4.0 technologies and the consequences of the use of artificial intelligence (e.g., ChatGPT) in education.

With the presentation of the proposal and the reflections on the potential of the TPACK model on this work, we hope that will be possible to encourage other teaching professionals to consider technologies and active practices in the development of the planning of their disciplines, given the importance and contribution of the theme for constant improvement of the teaching-learning process and dropout reduction. Finally, we understand that education must accompany the development of society. Thus, in order for the teaching-learning process to be dynamic and real, the use of technologies in education is a path to be taken by all experienced and in-training teachers.

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6 References

Barcelos, R., Tarouco, L., Bercht, M. (2009). O uso de mobile learning no ensino de algoritmos. *Renote*, v. 7, n. 3, p. 327-337.

Braga, B. H. C. A., Yada, M. M. (2021) Ferramentas da gestão da qualidade e sua importância para o desenvolvimento das organizações. *Revista Interface Tecnológica*, v. 18, n. 2, p. 600-612.

Gonçalves, B. S. O., Pereira, C. P. (2016). Aplicação de uma Dinâmica para o Ensino-Aprendizagem da Gestão da Qualidade. *Revista Brasileira de Gestão e Engenharia*| RBGE| ISSN 2237-1664, v. 7, n. 1, p. 94-106.

Goulart, M. B., Da Costa, P. K. A., Pereira, A. L. (2018). A integração das TDIC na formação inicial de professores de matemática no Brasil: uma análise a partir dos projetos pedagógicos. *Olhar de Professor*, v. 21, n. 2, p. 351-367.

Mishra, P., Koehler, M. (2006). Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge. In: *Teachers College Record*, 108(6), 1017–1054.

Niess, M. L. (2005). Preparando professores para ensinar ciências e matemática com tecnologia: desenvolvendo um conhecimento de conteúdo pedagógico de tecnologia. *Ensino e Formação de Professores*, v. 21, n.5, pág. 509-523.

Ribeiro, P. R. L., Piedade, J. M. N. (2021). Revisão sistemática de estudos sobre TPACK na formação de professores no Brasil e em Portugal. *Revista Educação em Questão*, v. 59, n. 59.

Sampaio, P. A. S. R., Coutinho, C. P. (2014). Integração do TPACK no processo de ensino/aprendizagem da matemática. Revista Paidéi@- *Revista Científica de Educação a Distância*, v. 6, n. 10.

Shulman, Lee (1986). Those who understand: Knowledge growth in teaching. In: *Educational Researcher*, 15(2), 4–14.

Shulman, Lee (1987). Knowledge and teaching: Foundations of the new reform. In: *Harvard Educational Review*, 57(1), 1–22. Teacher Education, 21, 509–523.

Silva, A. J. C. (2020). Guia prático de metodologias ativas com uso de tecnologias digitais da informação e comunicação/ Alexandre José de Carvalho Silva. *Lavras*., UFLA.

The reformulation of methodological strategies in a Physics course - implementing assessment by competences in an Engineering program

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Abstract

The Brazilian engineering programs are required, according to the new curriculum guidelines, to implement competence-based assessment in their pedagogical projects. Therefore, the Maua Institute of Technology has been promoting discussions since 2020 to reformulate its programs to comply with this demand. The reformulation aims to restructure the organization and to define the contribution of each course into the general engineering programs competences while reformulating their methodologies to demonstrate the development of these competences by the students. This paper presents this reformulation carried out to implement competence-based evaluation in the core physics course, in this University Center. Additionally, it discusses the desired evidence that validates the development of the competence's expectations, as well as the process of adopting headings, particularly in the development of laboratory activities. The paper presents the sequence of discussions, adopted premises, initial proposed plan, implementation in 2021, changes in 2022, and adaptations for 2023. It also includes the professors' perception of the discipline and the history of the teachers' training to develop this new competence-based assessment culture.

Keywords : Active Learning; Engineering Education; Physics.

1 Introduction

According to the new curriculum guidelines (MEC, 2019), Brazilian engineering programs are required to implement competence-based evaluation in their pedagogical projects. The Maua Institute of Technology - University Center has been promoting discussions since 2020 to reformulate its disciplines and structure its organization to define the contributions of each discipline to the course competences. The goal is to reformulate the methodologies to demonstrate the development of these competences by students. This paper presents the reformulation carried out to implement competence-based evaluation in the core physics course of basic engineering programs at the Maua Institute of Technology - University Center. It also discusses the desired evidence that validates the development of competence expectations and the process of adopting headings, especially in the development of laboratory activities. The paper details the history of discussions, the adopted premises, the initial proposed plan implemented in 2021, the changes made in 2022, and the adaptations carried out for 2023. It includes the professors' perception of the discipline and the sequence of the training provided by the teachers to develop this new competence-based assessment culture.

2 The definition of an evaluation model - history of discussions performed

The discussion about assessment per competencies in science subjects, along with engineering programs at the Maua Institute of Technology - University Center, was initially presented in Cutri (2020), notably focusing on the search for evidence of competence development and the application of rubrics for applied physics projects. The Physics I course is part of the basic core of Engineering and is taught through two 50-minute theory classes and two 50-minute laboratory classes. Initially, the group of professors who teach the course discussed whether the competencies to be described should be correlated with those predicted in the course DCNs or if they would be totally independent. The decision was made to link directly the competencies to be developed in the course to those planned in the new curriculum guidelines (MEC, 2019) in order to promote alignment with legislation. So, in the Physics subject, the following educational goals are predicted by Article 4 of the DCN (MEC, 2019):

II - to analyze and understand physics and chemistry phenomena through symbolic, physical, and other models, verified and validated through experimentation:
- To be able to model phenomena, physicists and chemists' systems, using mathematical, statistical, computational, and simulation tools, among others.
- To predict the results of the systems through the models.
- To conceive experiments that generate real results for the behavior of phenomena and systems under study.
- To verify and validate your models through suitable techniques.
V - to communicate effectively in written, oral, and graphic forms:
- To be able to express oneself adequately, whether in the homeland language or in different languages from Portuguese, including through the consistent use of digital information and communication systems (TDICs), always keeping up-to-date in terms of available methods and technologies.
VI - to work and lead multidisciplinary teams:
- To be able to interact with different cultures through work, in face-to-face teams or at a distance, in order to facilitate collective construction.

Once the competencies to be developed throughout the course were defined, the evidence that would support this objective and the methodologies that should be used to promote the development of these competencies in students were also defined. Examples are presented in Table 1.

Table 1 – Example of evidence for the development of competences

Competence	Example of Evidence
To analyze and understand physical and chemical phenomena by using symbolic models, physical and others, verified and validated per experimentation	To accomplish laboratory experiments (activities in both individual and team forms) and develop a half-yearly project with greater complexity (individual and team activities), which will include the elaboration of a paper and an oral presentation. To successfully complete the micro activities in theory classes on Fundamentals of Physics with Engineering Problems.
To communicate effectively in the written , oral and graphic form	By developing simplified scripts that emphasize modeling and comparison between the predicted models and experimental outcomes. To develop a report (based on the model of a scientific paper), prepare a seminar, and deliver an oral presentation as part of the semester project.
To work and lead multidisciplinary teams	To properly conclude the weekly activities in group performed during experiments and the half-yearly project carried out in the laboratory.

Source: Own

3 Premises adopted

The Physics subject has been developing the application of various active learning strategies in both theory and laboratory classes, such as problem-based and project-based learning, peer instruction, among others (Cutri, R. et al, 2016). Considering that education per competences is an educational model that uses learning, not time, as the metric of student success, the following premises were adopted to implement this new approach:

- Apply an evidence-competence approach in theory and lab activities.
- Use different learning strategies according to the evidence needed to promote the proposals for competences.
- Gradually implement education per competences, starting with the semester project developed in the lab class and evolving to all lab reports and theory activities, in order to promote the culture of competence development for teachers and students.

According to Cutri (2020), to implement education per competences, an educational objective must be set first (where we want to arrive), and key points (timeline) must be established to achieve that purpose. Thus, if the objective is to achieve a determined competence, it is essential to define when it must be achieved. At the same time, it is essential to establish the learning objectives (using Bloom's Taxonomy) that are intended to achieve and the expected results from students. Performance indicators that allow ranking the performance levels of the determined competence must be defined. The construction of these indicators must be based on evidence. The curriculum structure can predict the development of a certain competence in various subjects with growing levels of development.

The performance indicators or performance criteria are called rubrics (Holt, 2004), (Chan, C., 2015), (Arribas, 2019). Rubrics are scoring tools or classifications used to measure student performance and learning using a set of criteria and objectives. There is no unified set of rubrics, since the scoring rubrics may vary according to the different subjects and courses. There are three components in the headings, namely:

- Performance dimensions/criteria: the performance aspects that will be evaluated.
- Descriptors: characteristics that are associated with each dimension.
- Scale/level of performance: a rating scale that defines students' levels of mastery within each criterion.

4 Implementations and adaptations 2020, 2021, 2022 and 2023

During the academic year of 2020, a project-based learning approach was employed for the Applied Physics Project in laboratory classes, using a software simulator called "Speed Calculations for Traffic Accidents" (SCTA) (Gurgel et. al., 2015) (Stem, N. et al, 2022). Teams of 3 to 4 students in laboratory classes predicted the initial velocity of a car in some traffic accident situations, modeling, collecting data, and analyzing them using the mentioned simulator and able to identify possible driver infractions. Students were evaluated using rubrics, which was the first approach in a competence-based assessment.

In 2021, the Theory Class was improved by using micro activities (Stem, N. et al, 2021), (Stem, N.; Neto, O. Mattasoglio; Cutri, R., 2022), (Stem, N. et al, 2022), and the Applied Physics Project with the rubrics was kept since all activities with students were developed online due to social distancing caused by the pandemic.

In 2022, in the Laboratory Class, the use of rubrics for all experiments was expanded. Generic rubrics were developed so they could be used in all kinds of experiments, allowing students to improve their self-recognition of competence development. The used rubrics are presented in Table 2:

Table 2 - Rubric proposal for laboratory classes

PROPOSAL (PHYSICAL AND MATHEMATICAL MODELING)	- Highlight: The modeling was clearly developed and explained - 4 points	- Proficient: The modeling was satisfactory, however missing some premises - 3 points	- Apprentice: The modeling presents some mistakes - 2 points	- Beginner: The modeling is incomplete - 1 point
ANALYSIS OF EXPERIMENTAL ERRORS	- Highlight: Experimental errors, the possible effects and ways to reduce them are discussed. They are able to estimate uncertainties and perform propagation when requested - 4 points	- Proficient: Experimental errors, the possible effects and ways to reduce them are discussed. They are able to appreciate uncertainties and realize propagation; however, it presents small errors - 3 points	- Apprentice: They present the errors; however, they make mistakes in calculating the uncertainty - 2 points	- Beginner: The discussions about errors are unsatisfactory - 1 point
CALCULATIONS	- Highlight: All calculations are shown and the results are correctly tabulated - 4 points	- Proficient: Some calculations are shown and the results are partially correct, but incomplete - 3 points	- Apprentice: Some calculations are shown and the results are tabulated, but they are partially incomplete and/or partially correct - 2 points	- Beginner: None of the calculations are shown or the obtained results present errors - 1 point
DATA	- Highlight: Professional appearance and representation of data in tables and/or graphics - 4 points	- Proficient: Representation requires data in tables and/or graphics. The graphs and tables are suitable with titles and units - 3 points	- Apprentice: Representation requires data in written form, but no graphic or table was presented - 2 points	- Beginner: The data is very inaccurate - 1 point
SCIENTIFIC CONCEPTS	- Highlight: The report shows a necessary knowledge about concepts involved in the experiment - 4 points	- Proficient: The report shows a necessary knowledge about most concepts involved in the experiment - 3 points	- Apprentice: The report shows a limited knowledge about most concepts that are involved in the experiment - 2 points	- Beginner: The report shows an unsatisfactory knowledge about most of the concepts involved in the experiment - 1 point

Source: authors

The generic rubric developed can be used for all experiments that will be carried out throughout the year. Using the same rubric for evaluating student learning makes it easier to promote student evaluation.

This proposed rubric was applied to teams of Physics I laboratory students in the 1st and 2nd semesters of 2022 and is being applied in the 1st half of 2023, allowing students to receive feedback and recognize the areas that need improvement.

For 2023, we intend to continue using a competence assessment portfolio (including micro activities, seminars, lab experiment reports, project-based learning approaches, demonstrations in theory class, among others) to continue promoting self-recognition of student learning journeys.

4.1 Applied Physics Project - “Speed Calculations for Traffic Accidents” – SCTA

Using a simulator software "Speed Calculations for Traffic Accidents" – SCTA (Gurgel et. al., 2015) (Stem,N . et al, 2022) students must study the process of collision in a real situation, developing a role similar to the one performed by a forensic investigator where by means of the skid mark and type of pavement he can estimate the initial vehicle speed. In the Physics laboratory, teams of students must: 0) Read the original paper about

"Speed Calculations for Traffic Accidents" and pay attention for general teacher's explanation during class laboratory, 1) Use Design Thinking methodology for project planner, 2) Do Physical modeling of the phenomenon trying to extend the model that was presented in the original paper, 3) Do simulations and check model's validity (by means of graphic analysis and comparing the fitted curves to the model predictions), and 4) Prepare a presentation about the selected traffic accident scene, explaining the model of the original paper, and presenting their graphic analysis, as well. In this way, through a contextualized problem, we intend to develop physics modeling competencies and soft-skills like teamwork, oral and written communication skills. Their final presentations were performed to the whole class and they were evaluated by rubrics. At the end of each final presentation teachers showed both the good points and the points that had to be improved to the teams. In order to verify the students' perception regarding the development of the project, a Likert-style questionnaire was applied. In 2020, 70 responses were received from a universe of 600 students (approximately 12%). More than 66% of the students found the theme of the project interesting or super interesting, and for more than 88% felt the time was adequate to carry it out, 93% of the students found the guidelines for the project adequate, and for 96% the previous presentation of the rubrics helped them to better prepare the work. For 82% of the students, the project improved the understanding of the theory and for 82% it presented applications involving physics applied to engineering.

5 Qualifications carried out by the team of professors of Physics

The culture of competence assessment portfolio by teachers has also been promoted through an institutional teacher development program called "Professor Academy" (Mattasoglio Neto, O., 2022), which aims to promote training and discussion of methodological approaches. In this competence-based education area, the following workshops have been conducted:

Year	Theme	menu
2020	Teaching by skills and planning per competences	- What are the learning objectives that should be observed? What is expected of course graduates?
	Assessment per Competences	- How to evaluate competencies? What is a rubric? How to develop rubrics?
	How people learn	- Bloom's taxonomy, learning by doing, and learning objectives.
2021	Competence Based Assessment Implementation using Rubrics in Open LMS	- Introducing the rubrics tool present in OpenLMS (Moodle) that allows the use of its own virtual learning environment for using rubrics. The feedback is delivered to each student individually.
2022	Institutional Event - Good Practices for Competence Based Assessment Implementation	- Sharing of good practices among university teacher staff.

The qualifications provided by Professor Academy have allowed for the maturation and improvement of competence concepts and methodological discussions, benefiting both teachers and students.

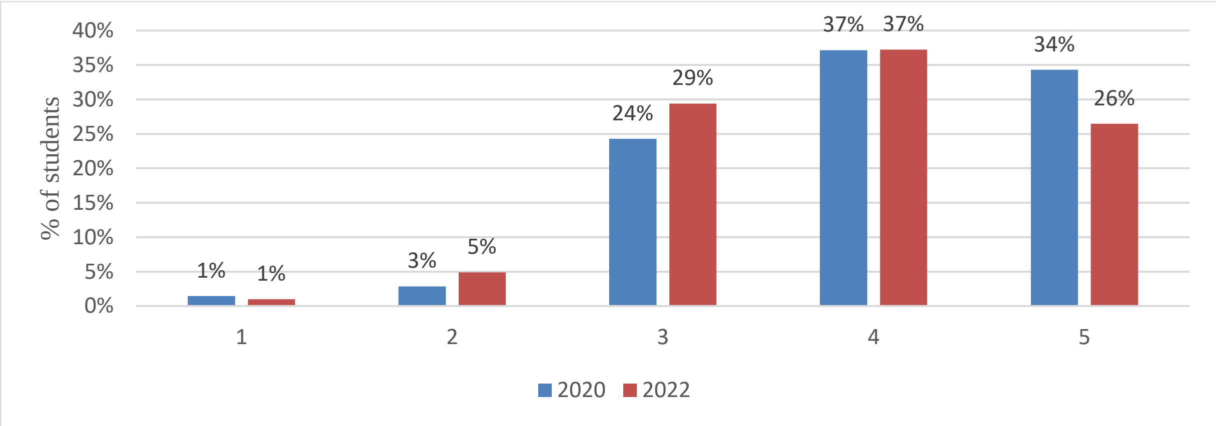
6 Perceptions

6.1 Student's perceptions

To check students' perception of rubrics, a five-point Likert scale survey was conducted. The survey asked students about their attitudes, teamwork, project management, and learning management attitudes. In 2020, after the PBL Project development, the survey was applied to a total of 600 students, with 70 responses received

(12% of the total number of students). The survey was not applied in 2021 due to the pandemic. In 2022, with a total of 424 students, 103 responses were obtained (24% of the total number).

Question: On a scale of 1 to 5, where 1 is "not helpful at all" and 5 is "helped significantly", did the rubrics that evaluated specific dimensions and performance levels help in better preparation for that activity?



In 2020, the use of rubrics helped 71% of students in grades 4 and 5 to better prepare for activities. However, in 2022, the percentage decreased to around 63%. This was very likely due to the fact that, in 2020, rubrics were only used for the PBL project at the end of the semester, while in 2022, rubrics were used for all activities during the year.

6.2 Perception of subject teachers

During the implementation of the Competence-Based Assessment, the team of Physics teachers held several meetings to discuss ways to improve the process. For teachers, the greatest challenge was to rephrase the form of presentation of the subject in order to better highlight the competences that will be developed in the respective activity. This did not only involve changing the title of an experiment or including the list of competences, but rather reformulating the teaching and learning dynamic in class. This was done with the aim of helping students recognize and construct their competences by using active learning approaches to work at the highest levels of Bloom's taxonomy.

A major challenge was creating rubrics that would include only a few performance levels and relevant indicators. Initially, teachers tended to imagine a small differential evaluation for each desired competence, which could result in transforming the new assessment into a numerical scale from 0.0 to 10.0, which should be avoided.

The use of evaluations per competence increased the time spent on the evaluation process due to the constant and necessary reflections and feedback to be given to students. However, improving rubrics and providing constant feedback to students is crucial to help them learn to recognize whether they are competent in a specific indicator.

7 Final considerations

In the Competence Assessment Culture, the chosen strategies and evidences must be constantly revisited by the teaching team to improve both the subject and the reflection process that leads to continuous self-improvement learning for the student.

8 References

Arribas, E. et al Development of a laboratory practice for introductory physics courses using a rubric for evaluation by competences, 2019 J. Phys.: Conf. To be. 1287 012025

Chan, Cky . "Rubrics for Engineering Education", Engineering Education Enhancement and Research Asia (E3R Asia), 2015. - Available at : https://hke3r.cetl.hku.hk/pdf/Rubrics-for-Engineering-Education.pdf - - Access on : 29 Nov. 2019.

Cutri, R.; et al. Ten Ways to Improve Learning Physics as Part of an Engineering Course. ASEE Annual Conference & Exposition, 2016, New Orleans. Annals. Louisiana, 2016.

Cutri, Rodrigo; Gil, HAC; Freitas, PAM. Assessment per skills ? An application proposal _ in engineering disciplines . _ In: XLVII Brazilian Congress of Education in Engineering (COBENGE), 2020. XLVII Brazilian Congress of Education in Engineering (COBENGE), 2020.

Gurgel, WP; Gomes, LP, Ferreira, LC And Gester, R., MR, Calculation of velocity in traffic accidents: development of software for forensic physics research, 2015 sai intelligent systems conference (intellisys), 2015, pp. 1045-1048, doi : 10.1109/intellisys.2015.7361272.

Holt Rinehart& Winston; Holt Science & Technology Assessment Checklists & Rubrics Paperback – Teacher's Edition, January 1, 2004 available at : http://lp3.unej.ac.id/wp-content/uploads/2017/01/East-Orange-Scoring-Rubrics-more-complete.pdf - Access on : 29 Nov. 2021.

Ministry of Education - Resolution No. 2, of April 24, 2019 - Establishes the Guidelines Curriculum Nationals of the Undergraduate Course in Engineering . Available at : http://portal.mec.gov.br/component/content/article?id=12991 Access on : 29 Nov. 2019.

Mattasoglio Neto, O.. Creation , development and structuring of the Academy of Teachers of the Mauá Institute of Technology . In: Octavio Mattasoglio Neto, Renata dos Santos, Terezinha Severino da Silva, Angelo Eduardo Marques Battistini , . V. Oliveira, Fransuze de. SAW. Baesso , José Aquiles Grimoni .. (Org.). Good training practices _ teacher in Engineering . 1st edition. Brasília: ABENGE, 2022, v. 1, p. 102-120.

Stem, N.; Neto, O. Mattasoglio ; Cutri, R.; Martin, PA. Extra-class online activities as a way of self - monitoring learning in physics teaching with students engineering course freshmen : Use of open- lms tools (questionnaire and H5P) . Latin American Journal of Development, vol. 3, p. 2213-2230, 2021.

Stem, Nair; Mattasoglio Neto, Octavio ; Alexandre Chaves Gil, Hector ; Cutri, Rodrigo . COMPETENCY-BASED ASSESSMENT - A PROPOSAL FOR APPLICATION IN BASIC ENGINEERING SCIENCES LABORATORIES. In: Brazilian Congress of Education in Engineering , 2022. Proceedings of the L Brasilian Congress of Engineering Education, 2022.

Stem, N.; Neto, O. Mattasoglio ; Cutri, R.. learning strategies _ active at discipline physics 1 in the engineering course at the institute technology mauá and skills development _ _ in a course mediated per Tecnologia / Active learning strategies in physics discipline of engineering course of maua institute of technology and competence development in a course mediated by technology. Brazilian Journal of Development, vol. 8, p. 543-566, 2022.

Certificates and skill levels. Gamification applied to learning goals

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Abstract

This paper examines the effectiveness of gamification techniques in Operations Research education, focusing on learning goals. The experiment has been going on with three to four classes for the past three years (six semesters) and involves gaming elements like levelling, certificates or badges, and avatars. The objective was to assess the impact of gamification on student engagement and their ability to tackle complex problems. Qualitative data analysis revealed increased student engagement and improved problem-solving abilities. These findings highlight the potential benefits of gamification as a pedagogical approach in Operations Research education.

Keywords: Gamification; Active Learning; Skills and abilities.

1 Introduction

It is said that Lord John Montagu (1718-1792), Count of Sandwich (a small town in the UK), was so obsessed with a sort of cards game (ancestor to bridge) that he often would not leave the game even in order to eat. On one of those occasions he was losing, he ordered his butler to bring him something to eat, then placed slices of roast beef inside a loaf of bread, and ate it with his bare hands, not taking his eyes from the cards on the table. That was the invention of the sandwich.

However, this experience is not unique to cards games. Many of us have experienced what is like to spend a night playing on a computer or video game, only to notice at early hours that we spent so much time immersed into them. What makes those games so addictive, and why, we instructors might ask, are our classes not like this? In trying to answer this question, many researchers and practitioners have been searching for elements typical of games and introducing them into education.

Our study enhances the literature by investigating the effectiveness of gamification techniques in Operations Research education. Through a three-year experiment and qualitative data analysis, we contribute to the question of how gamification impacts student engagement and problem-solving abilities. Our findings emphasize the potential benefits of gamification as a pedagogical approach, providing valuable insights for educators and researchers to enhance instructional strategies and improve learning outcomes in Operations Research.

One of the elements is constant feedback: the student progresses in particular abilities and gains levels in those. The student does that by monitored exercises, performing in-class activities, doing exams, completing team assignments, or interacting with others outside academia.

The abilities are associated with the learning goals of a particular course module and lead towards a major learning goal. Once they obtained certain levels in at least some of those abilities, students are awarded a certificate, relative to the learning goal of the module. Then the module is closed, and students are asked to move on to the developing of new abilities, aiming at a new certificate associated with a new major learning goal. This also mimics the existence of quests, typical of role-playing games (RPG). The way feedback is given also resembles a gaming experience. Students may be asked to create an avatar, and feedback is given online in a customizable environment which students are encouraged to help create.

All this draws the student's attention away from grading towards a pass-fail final result and to concentrate on achievable, immediate abilities and obtaining a certificate that has some actual meaning and that is not too far away in the time horizon. Moreover, the module system and the awarding (or not) of a certificate lead to a feeling of completion, also typical of the gaming experience.

The actual result of pass-fail in the course is decided by the student acquiring a minimum of the total number of certificates available. The method also provides instructors with frequent information on the development of students in abilities and learning goals established by the course.

This article is organized as follows. There is this Introduction (Section 1). Section 2, of Related Literature, in which we summarize some reviews that pertain to our objectives. Section 3, in which the system of abilities and certificates used is explained. Section 4, where the results obtained are discussed. Finally, Section 5, in which we present our conclusions and improvement opportunities.

2 Related Literature

This article is an account of the activities developed by our team and of the results obtained. It is an empirical study, so it does not intend to be a review of current and past literature on the subject. So, here we direct the reader to some review articles and summarize their results.

Borges & Reis (2014) define gamification as the use of game elements in non-game contexts to engage people in a variety of tasks. The authors made a review of works dealing with gamification in education. Some of their results were that most studies were published in conferences, focused on Higher Education, and aimed to foster the engagement of students through learning activities that build on gamification concepts. However, they also identified that there is a lack of approaches that combine gamification and Computer Supported Collaborative Learning (CSCL).

Surendeleg, Murwa, Yun, & Kim (2014) focus their review on asking what gamification is in the context of education and how to make education more interesting. The authors state that there are very few qualitative studies on the effects of gamification on students, a view also shared by Hamari, Koivisto, & Sarsa (2014).

Kalogiannakis, Papadakis, & Zourmpakis (2021) focus on a review of gamification specific for science education. The authors obtained information about theories underpinning gamification, gaming elements used, learning results, and motivational outcomes of papers produced from 2012 to 2020. They notice that gamification generates a large amount of data that can be studied, and that results on student learning still need to be more conclusive.

2.1 Classification of students in a gaming environment

Bartle (1996) developed a taxonomy of video game players, mostly based on players of multiplayer online games, usually involving large virtual worlds to explore and interaction with other players or characters. The taxonomy classifies players into four groups, according to their motivations to play games.

Based on Bartle's taxonomy, Marczewski (2015) developed a taxonomy for users or students in a gamification environment. The taxonomy is an expansion and adaptation of Bartle's work, and classifies students in gaming environments according to six classes.

- Achievers. Motivated by mastery of an ability or aspect of learning. They want to improve themselves, learn something new, and overcome challenges.

- Players. Motivated by rewards. They want to reap some rewards from their activities.
- Free Spirits. Motivated by autonomy and self-expression. They want to explore (new knowledge and new problems) and to create (solutions, understanding).
- Socializers. Motivated by relatedness. They want to interact with others and create social connections.
- Philanthropists. Motivated by purpose and meaning. They want to help other people improve themselves, teach others, with no expectation of reward. Their reward is to know they are helping.
- Disruptors. Motivated by change. They want to cause a disruption in a system, and instigate change, being it positive or negative.

2.2 Game design elements

In their study, Nah et al. (2014) identified eight game design elements commonly used in educational settings. These include points, levels or stages, badges, leaderboards, prizes and rewards, progress bars, storyline, and feedback. Points are often used to measure success, while levels or stages provide a sense of progression. Badges serve as tokens of accomplishment, and leaderboards create a competitive environment. Prizes and rewards give students an advantage, while progress bars provide a way to track personal progress. Storylines provide context for learning, while feedback is crucial for learner engagement and effectiveness.

Dichev and Dicheva (2017) conducted a review of articles on the empirical results of gamification elements in learning. The educational activities detected were classified as nontechnological and technological, including assessment, course participation, homework, learning interactions in virtual reality, online exercises, and more. The authors collected conclusive and inconclusive results, including improved participation and engagement, boosted communication and punctuality, and increased intrinsic motivation. The conclusive results showed an increased use of open learning environments, improved motivation, and no effect on performance. However, some of the conclusive results disagreed, and some inconclusive results created a stereotype threat in specific circumstances.

3 Gamification and educational activities

Our course, called "Models for Decision Making," is Operations Research emphasizing model building. Operations Research is the backbone of Production Engineering and explores the modeling and resolution of problems like production planning, logistics, stocks, designation, and simulation. In this section, we will explain the educational activities proposed for this course, how they are measured, and how the student is graded or rewarded.

3.1 The course

Models for Decision Making is currently divided into four Modules: Linear Programming, Network Problems, Stocks and Simulation, and Dynamic Processes. Linear Programming and Network Problems cover most of the usual Operations Research context, focusing on the modelling problems and their resolution using the Solver of Excel. Stocks and Simulation introduce some of the theories of stocks and Monte Carlo simulation. The main tool used in this module is programming in Python. Finally, Dynamic Processes studies interacting systems with systems of differential equations and solving them with Python.

The division into modules offers students with an attainable and relatively brief goal: to learn content, acquire abilities, and get a certificate.

3.2 Learning goals

The main learning goal of the course is for the student to be able to build mathematical models of some systems based on realistic problems and data, to solve those mathematical models, usually through computer-based methods, and then report results.

This major learning goal is divided into six others, each focusing on some aspect of the modelling process for types of problems, or on some abilities to be developed by the student. Each learning goal is subdivided into some abilities associated with them.

Based on the works of Bartle (1996) and Marczewski (2015), we present the Learning goals and abilities associated with them used in the course as follows.

Linear Problems. Ability to interpret a text related to a linear problem, build a mathematical model, solve the problem using Solver, and perform and interpret a sensibility analysis. It is subdivided into the following abilities.

Modeler. Ability to interpret and model a problem mathematically.

Grapher. Ability to solve a linear problem graphically.

Solver. Ability to solve a linear problem using the Solver of Excel

Analyzer. Ability to perform and take information from a sensibility analysis of the solution.

Network Problems. Ability to interpret, model, and solve a problem based on networks. It is subdivided by the type of problem to be solved.

Transporter. Modelling and solving a problem based on the transportation of goods at minimum cost.

Fluximizer. Modelling and solving a problem for maximizing flux through a network.

Path Finder. Modelling and solving a problem that minimizes the path (length or time) between nodes.

Designator. Modelling and solving problems that assign people or machines to jobs.

Stocks and Simulation. Ability to build models of the control of stocks to minimize stock costs and freight. Ability to use simulation of future events based on their past features.

Stock Master. Ability to build and solve models for controlling stocks.

Simulator. Ability to use Monte Carlo simulation applied to models of varying demand.

Dynamic Processes. Ability to model interacting systems utilizing systems of differential equations and solving them using programming in Python.

Dynamicist. General ability of the module.

Pythonese. Ability to generate Python code to simulate stocks, make Monte Carlo simulations, and solve dynamic problems—ability to search for needed code in the available resources.

Team Worker. Ability to assemble effective teams, work towards a desired goal, and manage eventual conflicts.

3.3 Certificates and levels

The names of the abilities sound like typical achievements in games, and that is on purpose. Each ability has ten levels. Assessments, activities in class, online exercises, or assignments are means for levelling up. Everything a student does leads to a mapping of points to those abilities. The mapping is described to the student at the beginning of the semester, and rules to obtain points are set. One of those mappings is shown in Figure 1.

Linear Problems				
Assessment	**LP Modeler**	**Grapher**	**Solver**	**Analizer**
Exercises of Class PL 1	0,2			
Exercises of Class PL 2	0,2	0,5		
Exercises of Class PL 3	0,2	0,5		
Exercises of Class PL 4	0,2		0,5	0,5
Exercises of Class PL 5	0,2		0,5	0,5
Activity 1	0,7	1		
Activity 2	0,7		1	1
Exam 1 – Block 1	3,8	8		
Exam 2 – Block 2	3,8		8	
Exam 1 – Block 3				8
Total by Ability	**10**	**10**	**10**	**10**

Figure 1. Mapping of assessments into abilities.

Exercises are all online, with instantaneous grading and the possibility of feedback. Activities are in-class problems to be solved in groups or independently, and with the help of the instructor. The aim is to provide a complex problem, leading to learning. Exams are also online, but individual, given in class. The grading is also instantaneous, but a grading by the instructor is also made.

Team Worker is assessed by a major project, divided into three parts. It consists of finding, modelling, solving, and communicating results for a real problem, of a real company, or based on real data. The first and second parts are written reports, and the last one is a video.

If students attain specific proficiency levels in certain abilities, they can earn a certificate. For instance, to earn the Certificate of Linear Problems, one must have a proficiency level of at least six in three out of the four abilities that are part of that learning goal. Therefore, it is not mandatory to have complete knowledge of everything, but rather to have a good understanding of most of the abilities.

What is the purpose of a certificate? It is yet another aspect of gamification. A certificate is a symbol of achievement, earned by the student and held by the student as an indication of his or her accomplishment. It signifies the completion of a module, a rite of passage. Students who have earned their certificate may then move on to the next level, while those who have not must work towards earning other certificates. Certificates may also be associated with medals or badges, which are commonly used in gamification.

Furthermore, certificates can be used by students to demonstrate their abilities or knowledge and can even be included in their curricula. Certificates also have the desired effect of leading the student away from worrying about grades, just obtaining what is necessary to pass, and towards the learning goals of the course. They set results and accomplishments that can be achieved in a relatively brief time (compared with the total length of the course), and that are focused on some set of abilities. As a result, they often become an object of desire by students.

Figure 2. Certificates, or badges, which may be obtained by students.

Levels are a way to give feedback to the student that is constant and automatic. In this sense, students may know how they are evolving in a particular ability, which gives them satisfaction, a sense of getting somewhere, like in video games.

3.4 Feedback

Leveling up and earning certificates provide students with immediate feedback and rewards, which can be incredibly motivating. However, the challenge lies in scaling this approach to larger classes. Technology can certainly be helpful, but providing accurate feedback still requires significant effort on the part of the instructor. Nonetheless, this process leads to a much deeper understanding of the various dimensions in which the student is developing within the course, benefiting both the student and the instructor.

In our course, we have used two different systems to give feedback to students. One is an aspect available to Blackboard, the virtual learning environment where we make most of our academic activities, like grading, offering material to students, or making assessments. It is called Achievements and may be programmed to trigger levels or certificates according to numerical results of a different assessments. Levels and certificates must be programmed by the instructor. Figure 3 shows a typical achievements page for a student in mid-semester.

Figure 3. Feedback of the achievements page of a student in Blackboard.

The other system for feedback is less technological, provides a more colourful way of feedback and depends only on access to the internet. We called it the Portfolio of the Student, a shared PowerPoint where each student has a page, which the instructor or the student may customize. How to guarantee anonymity in the display of achievements and certificates in such a system? Once more, the answer comes from gamification: we used avatars. In gaming, an avatar is a persona that represents the user in the gaming environment. Depending on the game, the avatar may be customized by the user. In our case, the student may create an avatar's name, a picture of the avatar, and customize his or her own page.

The avatar protects anonymity. The student may reveal his or her avatar to whoever he or she wants, but otherwise the name remains anonymous. The instructor feeds the page with eventual levelling up or obtaining of a certificate. Figure 4 shows three typical pages of Portfolios of the Student that have been customized by the student.

Figure 4. Three sample pages of the Portfolio of the Student.

4 Results

Before adopting the new grading system, certificates and levels of abilities, the new system was informally adopted together with more conservative grading assessments, giving them weights towards a minimum of five points at the end of the semester. Usually, students with the minimum grade also had half of the certificates, and students with the best grades had all six certificates. We continue to assign grades to all assessments, but the certificate system is official.

In order to understand the effect of gamification in our course, we analysed the averages of final grades in this course for the past few years and semesters. We only went beyond 2019, because the course faced several changes in that year, preserving its general structure until now, but quite different from what it was prior to that year. Figure 5 shows the average grades according to year and semester from 2019 to 2022. Error bars denote plus and minus standard deviation.

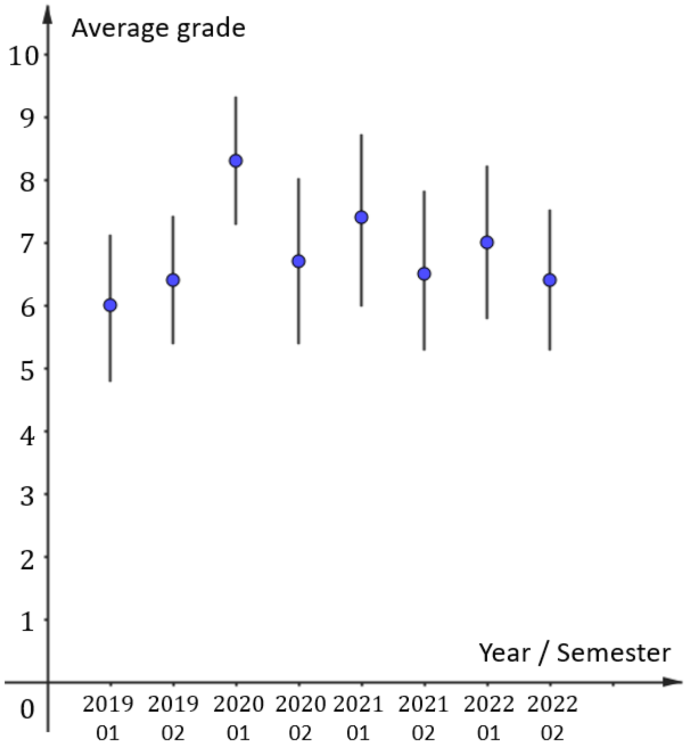

Figure 5. Average final grades, with error bars given by standard deviation, according to year and semester.

Upon analysis, there are no noticeable changes in grades during the semesters, indicating that there is no concrete evidence suggesting that the introduction of gaming techniques has improved student grades. Consequently, this places us among the group of articles with inconclusive quantitative effects of gamification in education (Dichev and Dicheva, 2017).

What we do have are qualitative results. Prior to the introduction of the gaming aspects, exams and exercises were much simpler, lacking complexity and depth. After gamification, they became more complex, with problems that are more open-ended and harder to solve. So, if grades have remained the same, even though assessment became richer than before, this probably bodes well for the new activities and scoring method that have been introduced.

Another qualitative measure is student engagement, which has risen in recent years. This is perceived by students' comments, both oral and written in their evaluations of the instructors. We also think we succeeded in making students care less about a final grade and more about acquiring certifications or mastering of some abilities based on the learning goals of the course.

5 Conclusion

This article showed the techniques and grading system we introduced into one of our courses to engage students and encourage them to develop abilities towards tangible goals, represented by the certificates. The findings reveal that gamification enhances student engagement and improves their ability to tackle complex problems within the course unit. This study adds value to the body of knowledge by providing empirical evidence on the positive impact of gamification in Operations Research education. Furthermore, it contributes insights into the potential benefits of incorporating gamified elements, such as rewards and game-like features, to enhance student motivation and learning outcomes. This research expands the understanding of gamification as a pedagogical approach and provides valuable information for educators and researchers to optimize instructional strategies in the field of Operations Research.

As further steps, we suggest the application of a qualitative survey with the students to understand their point of view about the gamification methodology. As temporal comparison and evaluation are difficult due to course changes and classes differences over the semesters, through a questionnaire answered by the students, they will be able to compare the gamification methodology with the traditional evaluation method used in other course units.

6 References

Bartle, R. (1996). Hearts, Clubs, Diamonds, Spades: Players Who Suit MUDs. *Journal of MUD Research, 1, 19*.

Borges, S. & Reis, H. (2014). A systematic mapping on gamification applied to education. *Proceedings of the 29th Annual ACM Symposium on Applied Computing - SAC '14*.

Dichev, C., Dicheva, D. (2017). Gamifying education: what is known, what is believed and what remains uncertain: a critical review. *Int J Educ Technol High Educ 14, 9 (2017)*.

Hamari, J., Koivisto J, & Sarsa, H. (2014). Does Gamification Work? -- A Literature Review of Empirical Studies on Gamification. *47th Hawaii International Conference on System Sciences, Waikoloa, HI, USA, 2014, pp. 3025-3034*.

Kalogiannakis, M., Papadakis, S., Zourmpakis, A-I. (2021). Gamification in Science Education. A Systematic Review of the Literature. *Education Sciences, v11 Article 22 2021*.

Marczewski, A. (2015). User Types. In *Even Ninja Monkeys Like to Play: Gamification, Game Thinking and Motivational Design* (1st ed., pp. 65-80). CreateSpace Independent Publishing Platform.

Nah, F. F-H, Zeng, Q., Telaprolu, V. R., Ayyappa, A. P., & Eschenbrenner, B. (2014). Gamification of Education: A Review of Literature. *International Conference on HCI in Business, Lecture Notes in Computer Science 8527, pages 4021- 409, (2014/6/22) Springer, Cham.*

Surendeleg, G., Murwa, V., Yun, H-K, & Kim, Y.S. (2014). The role of gamification in education – a literature review. *Contemporary Engineering Sciences, Vol. 7, 2014, no. 29, 1609-1616*.

Active Learning Approaches Applied in Teaching Agile Methodologies

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Abstract

We need to modernize education to form adaptable leaders who can tackle evolving challenges in our dynamic world. Insper's computer science program is designed to reflect this need with an innovative infrastructure, curriculum, and industry partnerships. We use active learning methodologies to teach agile methodologies and develop soft skills to solve real-world problems. Our focus is on non-violent communication, feedback techniques, and teamwork, along with constant interaction with industry professionals who share their experiences with students. Our goal is to provide students with a well-rounded education that equips them for success in the digital age. This work-in-progress research project describes our approach to teaching and our objective to prepare students for the future in the context of an innovative first semester experience on a CS program.

Keywords: Active Learning; Engineering Education; Developer Life; Agile Methodologies; Soft Skills.

1 Introduction

Computer Science education has been evolving to keep pace with the rapidly changing technology landscape. Venkateswaran (2022) notes that one reason for this evolution is to bridge the gap between industry needs and academic training. Disciplines such as Software Engineering, which were not previously part of the curriculum, are now mandatory, covering topics like Agile Methodology, Scrum, Kanban, and Lean. Soft skills development has also become a major focus, as software engineering professionals often collaborate with people from diverse cultures and time zones.

Active Learning approaches have been used in computer science courses as an alternative to passive and sequential teaching methods. The active learning approaches include hands-on activities, problem-solving, projects, collaboration learning, and other interactive practices.

In this paper, we describe the approaches used to teach agile and develop soft skills in an undergraduate Computer Science course at Insper Institute. The course, called Developer Life, is offered in the first semester of the program, and covers topics such as algorithms, logic, programming, design, agile methods, and soft skills. The course is distributed throughout the semester, with emphasis on hands-on activities, real-world problem-solving, and constant interaction with industry professionals.

2 Literature Review

In recent years, considerable research has discussed and shared active learning practices to teach agile methods and soft skills in computer science courses. This section has described the studies that guided the research.

2.1 Active Learning Approaches

Active learning is a student-centered approach to teaching and learning and can lead to more meaningful and effective educational experiences. In this approach, students participate more actively rather than passively receive information from the professor.

2.2 Active Learning Applied to teaching Agile Methodology and Soft Skills

Agile is a collaborative and iterative approach to software development. Active learning has been used to help teams to understand better and implement Agile practices and principles. Both strategies go very well together, since Agile focuses more on having quality implementations and productive interaction between team members, which required active participation on the part of the whole team.

The work of Polack-Wahl (2012) used active methodologies like practical games on the context of a half day workshop to teach agile methods. Some of the Games include the marshmallow tower challenge, collaborative origami.

Tribehorn (2021) exemplified active learning of the who software development lifecycle, mirroring the real-world practice in a twice a week 85 minute class. They implement six agile ceremonies: daily stand-up, sprint planning, retrospectives, sprint review, short iterations, planning poker to guide the students throughout the semester project. This work reported that they had both the professor playing the role of a client and a real client from the industry at some editions of the class. Soft skills approached were communication and negotiation, as requirements were kept evolving to simulate a real software project.

Another strategy on the context of a work-based degree was reported by Barr (2022), where a CS program alternates between periods in the industry (80%) with periods in the classroom (20%). Their approach teaches agile development and software testing in class in conjunction with a work-based module where students will harden the learned concepts in practice. They emphasize that his approach enables student confidence. Students are able to collaborate on their professional teams from the start and also are not afraid to ask questions at the workplace.

Finally, Agile methods have been proposed as a way to structure learning itself in Angellacio (2011), where learning of software concepts where planned as a sprint, where the the sprint planning involved studying the concepts and the end of the sprint corresponded to a demo were a software that involved the concepts was demonstrated.

2.3 Active Learning Applied to teaching Soft Skills

Developing soft skills is crucial to the modern workplace and highly valued by the software industry. *Soft skills* are a attributes and abilities that enable individuals to interact effectively with others. Some active learning approaches could be applied to develop soft skills, such as communication, teamwork, empathy, emotional intelligence, and collaboration.

Techniques such as reflection, group discussions, case studies, and group projects could contribute to student development.

3 Some Approaches to Teaching Agile and Soft Skills

3.1 Computer Science Course at Insper

This computer science course was created in 2021, starting in the first semester of 2022, with 30 students. In the first semester, the students have only one course called Developer Life. The main idea of this course is allowing students to experience a little of how is the routine of a software engineer. During the course, they are exposed to various computing disciplines such as agile methods, design (UX and UI), algorithms, programming logic, and problem-solving.

The focus of this paper is to describe some approaches that have been used to teach agile methods and soft skills.

3.2 The Classroom Setup

During the course, students developed four main projects, the first and second by themselves, the second in pairs, and the third in groups. The last project is the Sprint Session, where they work on a real problem proposed by a real client. This problem is brought up by some professionals from industry with predefined user stories. The initial two projects are designed for individual work, aiming to introduce students to the Python programming language, computational logical thinking, and effective learning techniques. In the third project, students transition to collaborative work in pairs, emphasizing the importance of non-violent communication, task management, organization, and version control practices. The final project presents even more significant challenges as teams expand to include 4 or 5 members. In this stage, the students face increased complexities in code organization and versioning while also dealing with a real client who demands tangible results and frequently changes project requirements.

It is the second cohort of the CS program, with 45 students.

3.3 The Agile Approach

Agile methodologies are widely used in industry around the world. According to the VersionOne report (2023), agile teams have used many methods in recent decades to guide software development teams. One of the most used is the Scrum framework, which students start using at the beginning of the course.

Students have a 2-hour agile and soft skills class at least once a week. In addition, they have an additional 1.5 office hours of the professor's time, which they can use to do exercises and resolve doubts on the subject. Usually in this course the “office hours” take place in the students’ classroom.

The schedule for the first semester of 2022 includes subjects such as Agile Principles and Values, Scrum board, ceremonies, user stories, activities, T-Shirt measure, and Scrum roles. They starting use this concept in the third project when they work in pairs on a game project.

3.3.1 Active Learning Approaches used to teach Agile

During the Developer Life course, some active learning approaches are used to teach the agile subject:

- *Problem*-Based *Learning*: Throughout the course, students learn to develop a system that solves four different problems. The first and second problems require the development of a game with specific requirements set by the professors. For the third project, students create a game and a website while defining their own requirements and story. Finally, students collaborate with an industry customer to develop a non-game system that addresses a specific problem. This project requires students to use both front-end and back-end knowledge to implement the system, with requirements and stories defined by the customer.
- *Scrum framework:* In the projects, they followed Scrum practices and ceremonies to manage development and teamwork. It is essential to highlight that it happens in the last two projects, where they work in pairs and groups. We recommend using these artifacts, but they are not considered for the evaluation. They still used the Scrum framework in the second semester to solve real problems. Then they are evaluated strictly considering the Scrum framework. The main objective is to introduce

the values, culture, and mindset of Agile methodology to the team to demonstrate the importance of project success. This will also enable them to understand the challenges of working together as a team to solve real-world problems, with regular meetings and direct interaction with the customer. The use of Agile methodology will help manage these challenges and contribute to the project's success. By emphasizing the Agile values of collaboration, communication, flexibility, and customer focus, the team can create a culture of transparency and continuous improvement, ultimately leading to a more efficient and effective project management process.

- *Academy and Software Industry connection*: During the semester, students have consistent and valuable interactions with industry professionals who share their experiences, challenges, advice, and the latest technology, methodology, and frameworks used in recent projects. In the first semester of 2022, students heard from three senior women in the technology market in Brazil and Canada, as well as two senior men in the Brazilian software industry, and a US-based Agile consultant. In the first semester of 2023, students had the opportunity to learn from an American Agile expert and a CIO leader from a bank company who visited the course. These interactions provide students with insights into real-world industry practices and help them prepare for successful careers in the field.
- *Hands-on activities*: The course is designed to be highly interactive and hands-on, providing students with ample opportunities to create, develop, and refine their skills. Most of the content is delivered through practical activities that enable students to engage with the material and apply it in a real-world context. This approach allows students to build their skills through trial and error, receive feedback from their peers and instructors, and refine their work based on that feedback. By emphasizing hands-on activities, the course aims to foster a dynamic and engaging learning environment that encourages students to explore their creativity, collaborate with their peers, and build their skills in a supportive and constructive setting.

3.4 The Soft Skills Approach

At the beginning of the course, students face several challenges as they adjust to new approaches to learning and navigate an unfamiliar environment with different rules and assessment methods. They also have the opportunity to interact with peers from diverse backgrounds and cultures, which can be both exciting and challenging. In addition, the course utilizes Agile methodologies, which place a greater emphasis on developing soft skills such as communication, collaboration, and adaptability. However, this can be particularly challenging due to varying levels of self-awareness and perception among students. Nonetheless, the course is designed to help students overcome these challenges by providing a supportive and inclusive learning environment, opportunities for peer-to-peer feedback and collaboration, and regular reflection and self-assessment exercises to help students build their self-awareness and soft skills.

3.4.1 Active Learning Approaches used to teach Soft Skills

The students are invited to follow some approaches from the beginning of the course, including:

- *One*-minute *talk:* Give a one-minute talk to the class about any subject they are comfortable discussing. The idea is to understand the level of safety they must discuss in public and the difficulty they must have in communicating their ideas. In the 2022 semester, we started with this initiative, but since not all the students wanted to be exposed in front of the others, this semester, we kept this talk but also created a new hands-on activity. We called this new activity, Agile Judgment.
- *The Agile Judgment:* Similar to the law judgment, in this activity involves several roles including the judge, witnesses for the defense and prosecution, the defendant and the accuser, defense and prosecution lawyers, and the jury. The primary goal of this activity is to provide every student with an

opportunity to develop and practice their communication skills. Those who feel comfortable speaking, negotiating, and presenting their ideas under pressure can opt for more challenging roles, while those who are less confident can choose more low-key roles to explore their communication abilities. During the first edition of this activity, two cases were discussed and judged.

- *Non*-violent *communication:* The professor delivers lectures on violent and non-violent communication examples, after which the students discuss and practice using non-violent patterns in their daily routines. This was implemented in the first semester of 2022. In the current semester, the course is experimenting with involving other professors and coaches (Figure 1) who conducted more than two workshops on this subject to support and enhanced the students' learning experience.
- *Happiness:* This class was inspired by the most popular Harvard class on Positive Psychology. In the first edition of this class, all hands-on activities were conducted in the classroom environment. However, in the second edition, we took the class to a green park in Sao Paulo called Ibirapuera Park (Figure 1). The main objective of the class is to motivate students to reflect on emotional intelligence and health, as well as to encourage them to practice some simple daily activities to improve their mental health. To achieve this, students participate in guided yoga, practice *ho'oponopono* and gratitude, and engage in mindfulness activities, such as observing the natural environment and listening to the sounds of nature. At the end of the practice, students choose a person who has had the most significant impact on their lives, write a post explaining why this person has influenced them the most, and share what they want to say to that person. Inspired by another scientific study(This study: https://www.youtube.com/watch?v=oHv6vTKD6lg), students are then invited to call that person and read their post to them.
- *Leadership skills and types*: Another important topic covered in the course is leadership skills and types, which is connected to the agile leadership style, such as servant leadership. The professor introduces and explains these concepts, providing relevant examples for students to understand. Following this, students are encouraged to debate this topic, allowing them to share their perspectives and ideas while learning from their peers. This learning approach helps reinforce the concepts and principles of agile leadership and develop students' critical thinking and communication skills.
- *ESG and ODS*: To align with our goal of developing future leaders who can contribute to a better world, we introduce and initiate discussions on the topics of ESG and ODS. As part of this module, students are tasked with researching and analyzing a company that promotes and applies actions connected to the ODS and/or ESG concepts. They identify the company, pinpoint which ODS or ESG items are related, and examine the actions taken by the company, delving into the reasons behind their approach. Through this exercise, we aim to develop critical thinking skills and an understanding of the importance of sustainable and responsible business practices.
- *Pitch Training:* At the end of the semester, students undergo training to prepare and deliver a well-crafted speech and presentation of their final project to the customer. This training focuses on enhancing their communication skills and ensuring that they can effectively communicate the key aspects and benefits of their project to the customer. The training also emphasizes the importance of delivering a polished and professional presentation, with clear and concise messaging that effectively conveys the project's value proposition.

Figure 1. The happiness class.

Figure 2. The Agile Judgement.

4 Outcomes and Teaching Perception

The students faced coding, team management, and organization challenges in the first two projects. Communication, code repository management, and conflicts were intensified in the third project. They realized the need for an effective approach and sought help to use the Scrum framework. They used a preliminary version of Scrum, including the board, prioritization, and Sprint planning. They followed a similar process in the next semester despite class size increase. Despite initial resistance, they saw the benefits of an organized and efficient approach to teamwork. Though the 2023 cohort was larger, similar problems and dynamics were observed.

The students' close and constant *connection with the industry* is a source of motivation for them, as they are inspired to face challenges and aspire to future positions in the industry. Each time a professional from the industry gives a talk, the students spend the entire week discussing the ideas, seeking advice, and reflecting on what they have learned. Many students even go the extra mile by sending a message and their curriculum vitae to the professional to analyse their suitability for the industry. The high number of questions during these talks is a clear indicator of the students' appreciation, often resulting in discussions that exceed the expected duration of one hour and last for more than two hours. The engagement of the students is remarkable, as they seek to learn from experienced professionals and gain insights into the real-world challenges they will face in their careers.

About the *happiness class*, one student shared their positive feedback, saying, "This class surprised me. Thank you so much." The happiness class provided a space for students to connect with themselves in a light and relaxed environment. This experience carried over into other classes, as students referenced the discussions and reflections from the happiness class in their other course activities. For example, a student says, "Professor, as you mentioned in the happiness class, I'm struggling with this problem and can't seem to find a solution. Maybe I need to take a break." This indicates that the content from the happiness class was relevant and applicable to their daily lives.

Regarding *non-violent communication*, it's great that the students are incorporating it into their interactions with each other. They started using it in a lighter tone, making jokes like: "I do not like your communication, colleague, I think this language is violent..." and as the weeks went by, being more emphatic and pointing out and suggesting better forms of communication when a colleague was upset or used an inappropriate term.

Concerning *one-minute talks*, over time, students did not want to make these presentations since it was voluntary and not mandatory, and the perception collected with conversations about the lack of interest in this action was that as it was not worth a grade, so they did not see many reasons to perform them.

Using *ESG and ODS* concepts to analyse a company that follows specific practices and programs in this area, students often face doubts and questions about which specific actions correspond to each goal and for what reasons. However, some students have shown enthusiasm towards initiatives related to gender issues, environmental sustainability, and animal welfare that are aligned with these concepts.

The *pitch* practice sessions proved to be highly beneficial in preparing the students for their final presentation to the customer, who was a partner from the industry. As the presentation was a crucial aspect of the course, the students devoted a significant amount of time to practicing and utilizing the guide provided in class. Despite feeling nervous, they felt more confident and well-equipped to deliver a compelling pitch, thanks to the practice sessions.

About the *agile judgment* (Figure 2), the students were more motivated after participating in the activity. During a brief discussion at the end of the practice, they expressed a desire to have another edition and judge more cases, allowing more students to develop their roles and have more opportunities to speak. They were super excited after seeing the first judgment case and the iterations during the trial were intense and constant. The students also suggested that future cases should be more detailed, which would allow them to bring and organize more elements to foster the debate.

At the end of the first semester in 2022, we conducted a questionnaire to evaluate the course in general, and the students expressed that they developed their ability to learn how to learn, *"The way in which the content was presented encouraged research and Insper's mode of learning how to learn."*.

When asked whether the dynamics on emotional intelligence and mindfulness contributed to their formation, 17 out of 26 students agreed or completely agreed.

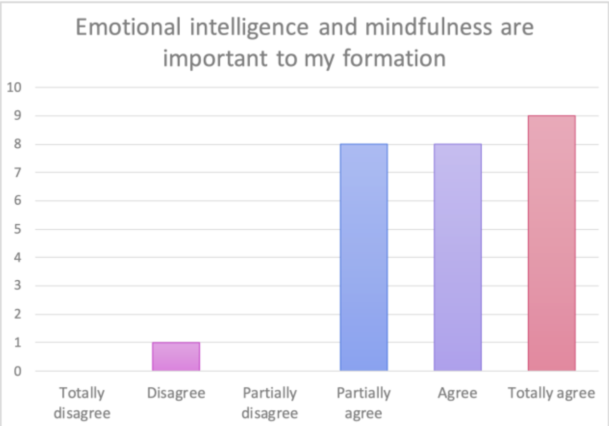

Figure 3. The impact of emotional intelligence and mindfulness on their knowledge

They also emphasized that the hands-on activities and course format helped them to learn. One student said, "Regarding the course format, I loved it. I had never experienced a hands-on teaching mode, and it really helped me to learn." They found the course provided a great real-life experience, with one student stating, "The Devlife discipline provided an excellent experience of a developer's life," and another student expressing that it was intense and productive learning, "Intense and productive learning. The format is more like professional life, allowing for autonomous learning and enough freedom.".

They also highlighted the benefits of the final project, where they had a customer from the industry, stating that it was an "Experience close to reality" and an opportunity to "Experience what it's like to deliver a project in the job market". They described the positive impact on teamwork and agile methods, saying that "It helped to have a better idea about working in a group and it helped in terms of organization with the scrum board". They mentioned that working with a real client helped to motivate the team and increased their maturity level, with one student saying, "When carrying out the project for a client, I felt much more mature." Another student added that it was a "real work experience that forced them to learn quickly and efficiently," while another described it as an "innovative" project. Also, 19 students completely agreed, 6 agreed, and one partially agreed that the last project contributed to their knowledge, as shown in Figure 4. Similarly, when asked if interacting with a real customer enabled better learning, the students gave the same answer, as shown in the same figure.

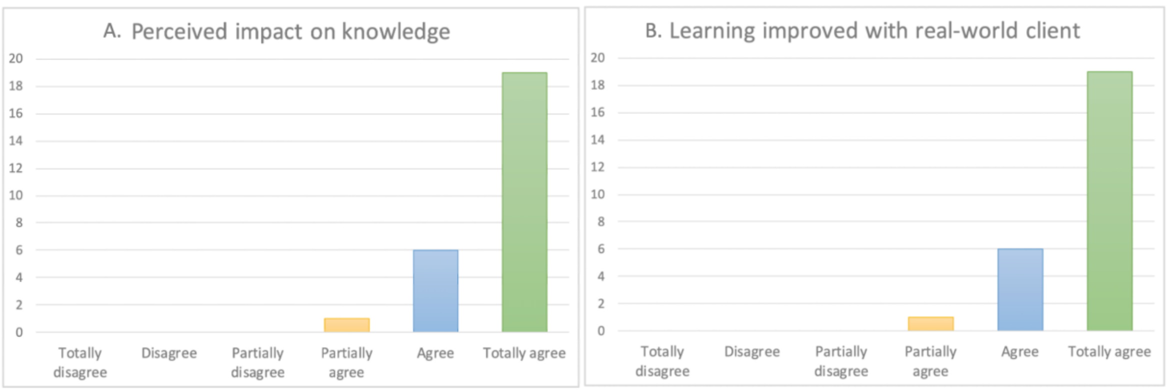

Figure 4. Perception by the students of the project's impact on their knowledge (a) and whether having a real customer enhanced their learning (b)

According to the professor perception, there is a significant impact on the students from these practices, in questionnaire that was made to evaluate the whole developer life course, they said: "Emulation of situations very similar to real work…", and "content with practical value. Interesting to learn. They complement each other and the logic of one helps others.", as the topics covered in the sessions continue to appear in other classes over time. These preliminary results provide support for the professor's perceptions and suggest that the students not only retained their learning, but also found value in the practices and enjoyed them. Furthermore, the results indicate that the students are capable of applying what they learned in different contexts.

5 Conclusion

To summarize, creating contemporary teaching methods that meet the needs and expectations of both new generations and the job market is increasingly challenging. Active learning approaches that encourage hands-on activities have shown promise for developing future professionals. In this paper, we describe some of the approaches we are testing in a computer science course during the first semester in 2022 and 2023. The first impression is that this activity is more attractive for the students and well regarded by the industry. In contrast to Dori's (2007) findings that students are resistant to a new learning approach, our perception is that when we offer classes following the traditional way [y of thinking, students complain about having fewer classes using active learning approaches. This report outlines our preliminary results with the approaches used and our perceptions of the results obtained.

In future work, we aim to collect evidence through questionnaires to gain a deeper understanding of the impacts on student training. Additionally, we plan to replicate this assessment to understand how the approaches evolve over time and across different generations and their potential effects.

6 Acknowledgement.

We want to express our sincere gratitude to all the students who participated in the course and contributed to its success. We also extend our appreciation to our colleagues in the field who face these challenges daily.

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7 References

Angellacio, M and Fanti, A. Design of Active Learning Strategy through Agile Development methodologies: a technological view. CECIIS 2011: Central European conference on information and intelligent systems

Barr, M, Somerville, D., Dziallas, S. How the First Year of a Work-based Degree in Software Engineering Prepares Students for Industry, 2022 IEEE Frontiers in Education Conference (FIE), Uppsala, Sweden, 2022, pp. 1-5, doi: 10.1109/FIE56618.2022.9962449.

Beck, K., et al., (2001) The agile Manifesto. Accessed in https://agilemanifesto.org/.

Ben-Shahar, T. (2006). Positive Psychology Course. Harvard University. Accessed in https://pll.harvard.edu/course/positive-psychology?delta=0.

Caceffo, R., Gama, G., Azevedo, R. (2018). Exploring Active Learning Approaches to Computer Science Classes. SIGCSE'18, February 21-24, Baltimore, MD, USA.

Dori, Y.J., Hult. E., Breslow, L., and Belcher, J.W. 2007. How much have they retained? Making Unseen Concepts Seen in a Freshman Electromagnetism Course at MIT. Journal of Science Education and Technology, 16(4), 299 – 323.

Graaff, E. d., & Kolmos, A. (2003). Characteristics of Problem–Based Learning. *International Journal of Engineering Education, 19*(5), 657-662.

Hazzan, O., Har-Shai, G. (2013). Teaching Computer Science Soft Skills as Soft Concepts. In Proceeding of the 44th ACM technical symposium on Computer science education (SIGCSE '13). Association for Computing Machinery, New York, NY, USA, 59–64. https://doi.org/10.1145/2445196.2445219.

Milczarski, P., Podlaski, K., Hłobaż, Q., Dowdall, S., Stawska, Z., O'Reilly, D. (2021). Soft Skills Development in Computer Science Students via Multinational and Multidisciplinary GameDev Project. (SIGCSE '21), March 13–20, Virtual Event, USA.

Polack-Wahl, J and Anewalt, K. , Workshop: Learning agile through active learning activities, 2012 Frontiers in Education Conference Proceedings, Seattle, WA, USA, 2012, pp. 1-1, doi: 10.1109/FIE.2012.6462354.

Tribelhorn, B., & Nuxoll, A. M. (2021, July), Using Agile and Active Learning in Software Development Curriculum Paper presented at 2021 ASEE Virtual Annual Conference Content Access, Virtual Conference.

Venkateswaran, S. (2022). Reflections on the Evolution of Computer Science Education. ACM SIGSOFT Software Engineering Newsletter Page 11 July 2022 Volume 47 Number 3.

VersionOne. (2023). State of Agile Report. Accessed in https://digital.ai/resource-center/analyst-reports/state-of-agile-report/.

Smart Digital Ecosystems for Cooperative Learning

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Abstract

On a large scale, the offer of digital technology helps to face two major obstacles to educational processes: the production of open digital resources and the offer of teacher training in a network and on an ongoing basis. Expressions such as learning ecosystems, intelligent environments to support learning, digital multimedia resources, and active methodologies are often mentioned. In addition to fads, the combination of these terms can lead to major transformations in educational systems. During an academic semester, we worked with 10 students from a graduate course in Computing at a Brazilian public university, in the seminar called Intelligent Ecosystems to Support Cooperative Learning. The Seminar was carried out, in its entirety, supported by active methodologies, with emphasis on the use of the pedagogical architecture "Debate of Theses". To consolidate the conceptual appropriation of the participants, we carried out and analysed two activities:: (1) the cooperative elaboration of a pedagogical architecture to be applied with Higher Education students and (2) the individual writing of an academic essay on the theme developed in the course. The analysis of the results was based on Jean Piaget's genetic epistemology, aiming to analyse the process of teachers' awareness, expressed in evolutionary levels of conceptualization of the approached themes. The evaluations carried out sought to focus on the students' conceptual understanding and resourcefulness in transposing the conception of new pedagogical possibilities into their teaching practices. The observed results allow us to indicate that the course proposal was successful, with most of the group (80%), showing changes in the level of understanding of the concepts of intelligent ecosystems, cooperative learning, and pedagogical architectures.

Keywords: Active Learning; Intelligent Digital Systems; Awareness; Pedagogical Architecture.

1 Introduction

Today we live in what has been called Digital Culture, which means that a large part of the transactions and records that, in the past, were carried out in person, are now carried out through digital interfaces and, often, computer systems. Purchases, payment of bills, obtaining documents, and scheduling medical appointments, among other transactions, are mostly carried out in an online system. Conversations, work meetings, and even social ones take place with the support of digital technologies. Social networks, for different interests, are part of this new communicational ecosystem, oftentimes, improperly using intelligence that hurts our individual freedoms.

The school also goes through this process of transformation, however, in some aspects, it walks with more caution. Some, out of fear, others because they know that the great result of education is in the formation of citizens committed to the well-being of society. This commitment involves the adoption of pedagogical proposals that stimulate the intellectual development of each one and the construction of a culture of peace. As Paulo Freire, one of the greatest pedagogues of the 20th century, points out, education cannot be considered a banking relationship, where the teacher deposits ideas and content, so that the student is "enriched" with the transmitted knowledge, to be used throughout the classroom. leaving school (apud Brighente and Mesquida, 2017).

The quest to understand and explain, from a scientific point of view, how human beings construct knowledge is recent. Without this knowledge, investment in education always runs the risk of wasting financial resources and compromising the formation of generations. The results obtained by cognitive psychology, which offers us theoretical support to rethink pedagogical approaches, have already been discussed since the end of the 19th century. However, the means of production of educational resources, the teacher training processes, still constitute major obstacles to quality improvement. The adoption of active methodologies has been discussed for a long time, which, as we know, is fundamental for learning. However, a large part of the pedagogical practices are still centered on the teacher, as the agent who has the power to teach.

The large-scale supply of digital technology has contributed to overcoming two major obstacles: the production of open digital resources and the offer of teacher training in a network and on an ongoing basis. Expressions such as learning ecosystems, intelligent environments to support learning, digital multimedia resources, open and distance education, and active methodologies are heard more frequently. In addition to the fad, the combination of these terms can contribute to an education revolution.

With the increasing capillarization of information, driven by the expansion of internet points and the mobile phone network, from the first decade of the 21st century onwards, the academic community has increased interest in the ecological conception of cognition and new initiatives and experiments have emerged on what it has been called the ecology of learning (Brown, 2000) (Richardson, 2002) (Jackson, 2013). In this scenario, we highlight 3 important proposals: a) learning by investigation; b) cooperative learning, and c) learning based on extracurricular experiences.

In the 90's, some changes in the way of seeing the internet, provided a greater approximation of users with the internet. Until then, users were mere consumers of content. Environments for discussion groups, the well-known forums, began to emerge. Next, the learning management systems (LMS), and after these, the virtual cooperative learning environments (VLE). We are now, for at least a decade, in the era of Smart Learning Ecosystems (SLE). The initiatives are quite diverse. Each prioritizes different aspects, although there are notable intersections (Spector, 2016; Silveira, 2020; Aguilar and Valdiviezo, 2015; García-Holgado and García-Peñalvo, 2017; Silveira, Cury and Menezes, 2019). In this work, we focus on supporting cooperative learning, a fundamental approach to the construction of knowledge from the ecological point of view of learning.

The present article focuses on the analysis of the students' conceptual understanding and resourcefulness in transposing new educational possibilities based on the eco-systemic view of learning into their pedagogical practices. After this introduction, in which we place the context of the research, we present in section 2 the theoretical foundation of the study. Section 3 is intended for a brief presentation of the experiment carried out, while section 4 describes the study methodology. Section 5 reports the data analysis and summary of results and, finally, section 6 presents the final considerations.

2 Theoretical Foundation

In this section, we present the main theoretical foundations considered in the present study. Initially, we present the concept of learning ecology, followed by a discussion of a pedagogical approach called pedagogical architectures, and finally, we present the concept of becoming aware in the context of genetic epistemology.

2.1 Learning Ecology and Intelligent Ecosystems

In the 1970s, Gregory Bateson (1972) elaborated the hypothesis that, similarly to biological systems, the mind works in an ecological way, that is, we perceive what is in the world and build knowledge, based on a process of interactions such as the physical environment and with other humans. Inspired by this work, the philosopher Pierre Levy (1990) elaborated, based on the new digital technologies, the proposal that he called towards a new Cognitive Ecology. In his work, Levy has already relied on the potential of communications brought by the Internet, in the production and use of hypermedia artifacts and the ability to carry out computer simulations.

The simulation of experiments, according to Levy, brought a new possibility both for science and for learning. With this approach, it is possible to create digital contexts for the observation and analysis of computational models for ephemeral, dangerous, or hypothetical events.

From the point of view of Brown (2000) learning does not occur directly from accessing information, whether it comes from a lecture by an expert, reading a text, or watching a video. Learning is situated, that is, it occurs during problem-solving, where we make use of information to plan the solution and subsequently apply it. When we are repeating a task that we have already performed other times, we just apply again what we already know. But when the problem at hand is slightly different, we need to adapt previous solutions to address the new problem. These adaptations can be conceived in dialogic processes with other students exploring and testing new possibilities. In other words, we always live in a network of interactions, without boundaries. We establish several relationships with content that we have access to, whether searching documents or conversations with third parties. The school cannot be focused only on the passive reception of content or to solve problems from a list presented by the teacher, it needs to offer the opportunity for the subjects to explore situations of their interests (POZO, 1994), approaching interests that approach to make feasible team building. Additionally, when completing the solution of a problem, we must perform metacognitive activities, to consolidate new learning, even seeking the elaboration of generalizations (Polya, 1978).

To support students in an ecological context, it is necessary to make available different computer resources (including Artificial Intelligence) to support the management of ongoing activities, facilitate access to related content, support approximation between partners based on the profile of academic interest, in the identification of external activities related to ongoing activities, the identification of opportunities in events, the exercise of metacognitive activities (Silveira, 2022).

2.2 Pedagogical Architectures

In the school context, teachers need to propose activities aimed at promoting the learning of the topics included in the syllabus. Following the precepts of learning ecology, we can organize micro-ecosystems to explore these themes. In our pedagogical work, we have adopted the concept of Pedagogical Architecture (PA) (Carvalho, Aragón, and Menezes, 2007; Castro, Menezes, and Aragón, 2020). According to the authors, a PA is a structuring support for the development of cooperative activities, based on Genetic Epistemology (PIAGET, 1972), the Pedagogy of the Question (FREIRE, 2012), and the Ecology of Cognition (BATESON, 1972). This concept is proposed in the context of Digital Culture and, therefore, assumes the use of digital technologies such as support for data organization, communication tools, and intelligent support for the mediation of learning and the evaluation process.

The conception of a pedagogical architecture is based on the definition of the following elements: Educational Objective; Support for the use of Prior Knowledge; dynamics of interactions (of the subject with the objects of study; Distributed mediation (interactions between peers); Mediation of the teacher) and Learning Assessment. For interactions, mediations (distributed and teacher), and intelligent computational support.

For each pedagogical activity, the teacher can design a specific architecture or instantiate a model available in the AP repertoire, available in the literature. The conception of computational support can be made possible using available communication and interaction technologies in composition with AVA environments or using specific environments made available by other users.

An example of architecture that already has its own environment for computational support is the Thesis Debate, one of the architectures used in the seminar presented in section 3. The Thesis Debate aims to support the cooperative construction of knowledge, consisting of a structured conversation that takes place based on a set of statements (theses) on a specific topic. The discussion unfolds in the following stages: Initial

Positioning/Argumentation, Peer Review, Reply, and Final Positioning/Argumentation. During the debate, the participant assumes the roles of "arguer" and "reviewer". For each statement, participants can access different points of view: their own, those of their reviewers, and those of the texts they review. This establishes a network of interactions among the participants, allowing the exchange of viewpoints and enabling the re-elaboration of their conceptions.

In the distribution of reviewers, the formation of discussion islands is avoided, favoring the circulation of ideas among all participants. Figure 1 illustrates the web of interactions for a debate with 5 participants.

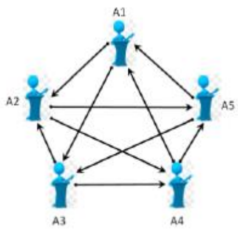

Figure 1: Network of interactions with 5 participants (Silva et al, 2020)

2.3 Conceptual Understanding from the Perspective of Awareness

In this investigation, we focus on the students' conceptual understanding of the topics covered in the Seminar, from the constructivist perspective of awareness.

Knowing is not just living, and experiencing, but organizing, structuring, and explaining what is lived, from action in the world (Ramozzi-Chiarottino, 1988). Objects and events acquire meaning when they are inserted into a system of relationships based on the subject's actions, which configures the construction of their mental structures. This construction starts in levels of practical intelligence, until the levels at which the subject reaches a conscious knowledge in the sense of a conceptual understanding.

Awareness is not a simple insight, in the sense of a sudden illumination that clarifies some reality hitherto hidden, without a transforming effect on it (Piaget ,1978) that can explain how an interiorized action transforms thought into a concept, essentially consisting of awareness in a conceptualization (PIAGET, 1974). It is produced by maladjustments because when we do something that does not produce the expected results, we seek to analyse and correct the action taken through active regulations. However, the process of becoming aware is not only constituted by inadaptations; it can be a process of thinking or explaining the process of action, in gradual awareness. There are constant searches for higher levels of knowledge that lead subjects to understand objects of knowledge.

In this process, the subject, initially, is aware only of the objectives and results of his actions so that, during the process, he gradually understands the intrinsic properties of the object of knowledge and the means used to carry it out. Therefore, in the process of becoming aware, there are intermediate moments that point to an incomplete awareness of the action, be it physical or mental. Thus, awareness is “a process of conceptualization that reconstructs and then goes beyond, in terms of semiotization and representation, what was acquired in terms of action schemes” (Piaget, 1978, p. 204).

This conceptualization process can be enhanced by a special form of interaction, which does not concern ponderable objects, but takes place through the “exchange of thoughts” between subjects. Such experiences can generate conflict situations, but, on the other hand, lead to cooperation, individual autonomy in relation to their peers, and respect for their positions. For exchanges to be balanced, overcoming situations of coercion, some conditions are necessary (i) a common system of signs and definitions (common language); (ii) a conservation of valid propositions (in the sense that they do not change at every moment) and (iii) a reciprocity of thought between the partners.

According to La Taille (1992), cooperation relationships precisely represent those that will enable the development of thought, since cooperation presupposes the coordination of the logical operations of thought of two or more subjects. In cooperation, there is an overcoming of asymmetry, imposition, and belief. What is identified are the exchanges of views and mutual control of arguments. Cooperation is the type of inter-individual relationship that represents the highest level of socialization that promotes development. We can add that it encourages respect for others and the critical spirit that leads to citizenship (LA TAILLE, 1992).

Considering the importance of cooperative actions (including active methodologies) for raising awareness, pedagogical actions should seek forms of interaction that help students to learn cooperatively. Carrying out pedagogical activities based on debates is an important proposal to encourage cooperation, as it consists of a social interaction in which different subjects exchange and confront, within a group, their respective positions on a problem, to propose a solution. Parrat-Dyan (2007) refers to discussion/debate as one of the elements that allow the subject to evolve from egocentrism to decentration, starting to understand and consider the point of view of other subjects. Thus, the debate allows the development of socialization and thought at the same time.

3 The Seminar on Learning Ecosystems

Throughout an academic semester, the Seminar on "Intelligent Ecosystems to Support Cooperative Learning" was conducted as part of a postgraduate course in Computing for both master's and doctoral students. The Seminar was fully implemented, employing active methodologies that were designed based on the Pedagogical Architectures Framework (Menezes and Aragón, 2018).

The Seminar was developed following the principles of learning ecosystems (Jackson, 2013), establishing a learning space in which theoretical contributions were explored and experienced through cooperative activities. Noteworthy among these activities were Cooperative Readings, a visit to an Academic Exhibition, and a structured collective debate utilizing the Thesis Debate pedagogical architecture (refer to section 2.2).

To reinforce participants', grasp of the conceptual content, two activities were carried out: composing an essay on the topic of Intelligent Learning Ecosystems and proposing a new pedagogical architecture. The data generated from these activities will be analysed in section 5.

4 Methodology

This study presents a qualitative research approach. According to Flick (2009), qualitative research allows studying experiences, interactions, and documents in their construction context to be able to consider their particularities. In qualitative research, we can use the text (in this case, academic essays, and proposals for pedagogical architectures) as empirical material and analyse it considering the perspectives of the participants and their knowledge.

The specificity of this qualitative case study (Yin, 2015) lies in understanding the students' awareness process, based on Jean Piaget's genetic epistemology.

To this end, we chose, as empirical material, written productions carried out during the seminar: (i) academic essays and (ii) proposals for pedagogical architectures carried out by students.

The subjects of the study are 10 students from a graduate course in Computing at a Brazilian university, in the seminar called Intelligent Ecosystems to Support Cooperative Learning. The students are professors from federal institutions of technical and technological education, all male, aged between 23 and 40 years. To ensure anonymity, students will be named by S1, S2, S3, S4, S5, S6, S7, S8, S9 and S10.

5 Analysis and results

Based on Piaget's theory of awareness (Piaget, 1978), evolutionary levels of conceptualization of the themes addressed in the seminar were elaborated: intelligent ecosystems, cooperative learning, and pedagogical architectures. To this end, the students' productions were analysed, identifying levels of understanding and descriptors, as shown in Table 1.

Table 1 - Levels of Awareness and its Descriptors.

Levels	Descriptors
Level I - Elementary Awareness: The concepts of intelligent ecosystems, cooperative learning and pedagogical architectures are understood, with a lack of differentiation between them and concepts characteristic of conventional approaches. As a result, the proposed architecture does not present its main components and, even, cannot be defined as an architecture. What is presented remains within a perspective of content teaching.	• There is a reproduction without criticism of the articles discussed in the synchronous meetings, in academic essay writing. • The selection of ideas does not privilege the establishment of relationships between concepts. • Assumptions and components of architectures are neglected, except for the technology component, which is overestimated. • The architecture proposal boils down to a collection of flowcharts and sequences of conventional activity steps.
Level II - Relative Consciousness: The concepts of intelligent ecosystems, cooperative learning and pedagogical architectures advance in their construction, but it is still a partial understanding. There is an advance in relation to conceptualization, however, when carrying out the transposition of ideas to the architectural proposal, it does so by merging characteristics/assumptions of architectures with transmissive/content teaching activities.	• The academic essay presents some reproductions, but also brings the author's ideas about the concepts. • Some relationships between the concepts are highlighted, still without deepening. Technology starts to be considered in the interaction with the other components, in a relational perspective. • The architectural proposal considers the idea of cooperative learning (building in groups and peer review) and is developed in stages. However, there is neglect of student autonomy and the mediating role of the teacher.
Level III - Reflected Consciousness: The concepts of intelligent ecosystems, cooperative learning and pedagogical architectures are understood and transposed to the proposed pedagogical architectures. At this level, reflected understanding allows the creation of architectures that respect their assumptions and are adapted to the target audience.	• The ideas of the studied authors are presented without a feature of reproduction. They are discussed and related. • The architectural proposal considers its assumptions and fundamental components (active pedagogies, cooperative work, peer review, teacher mediation, student protagonism, use of technologies, expansion of times and spaces). Technology starts to be considered in the interaction with the other components, in an ecosystemic perspective. • The steps are presented considering their meaning for the learning objectives to be achieved.

After the seminar, we analyzed the cognitive behaviors presented by the students.

Level I

Students S7 and S4 present cognitive behaviors characteristic of this level characterized by lack of differentiation between the ecosystemic approach and conventional, transmissive teaching. Although S7 manifests an awareness when he states that initially, he could not envision the potential of this theme, but he realized its value and how much he needs to evolve in his pedagogical practices, the proposals for pedagogical architectures are not based on the conceptualization of learning ecosystems but are based on activities focused on the transmission of content and with a focus on digital technologies. It is as if the simple introduction of technology could account for the necessary transformations in pedagogical practices. In this case, the conceptualization does not achieve enough stability to make it possible to propose an architecture, even if incipient.

Level II

Most of the students (S1, S2, S6, S8, S9, S10) presented cognitive behaviors typical of level II, in which advances are already manifested in the understanding of the concepts of intelligent ecosystems, cooperative learning and pedagogical architectures, but the understanding is still partial.

As an example, we can bring the writing of S1, in which he states that "these views of ecosystems may be merely theoretical, but they have enormous potential". This statement shows that S1 is able to see the importance of this approach, but still cannot conceive of its transposition into practice. This same understanding is expressed by S2, S9 and S10, when they register the need to consider an articulation between the pedagogical and technological aspects, but they overestimate the role of technology. Certainly, computer training leads students to privilege technological aspects to the detriment of epistemological and pedagogical aspects.

Similar behaviors are observed in relation to S8 when it manifests that from the review of texts and discussions it was possible to better understand the concept of intelligent learning ecosystems in which all components are interrelated. However, when translating this idea into the proposed pedagogical architecture, it highlights cooperative learning (construction in groups and peer review) but neglects important aspects such as student autonomy and the mediating role of the teacher.

Awareness of the relational approach, in which all components are considered in an articulated way and each component influences the others, is only completed at level III.

Level III

Subjects S3 and S5 exemplify a process of gradual awareness, which allows them to describe the eco-systemic approach through pedagogical architectures. At this level, reflected understanding allowed S3 and S5 students to create architectures that respect their essential components and are adapted to the target audience.

As an example, we highlight the architecture proposed by student S5, designed to favor programming learning, based on stages of elaboration of individual and group solutions and considering strategies to foster cooperation, network interaction, distributed mediation, reflection, and peer review as pillars.

Synthesis

In summary, the evaluations carried out sought to focus on the conceptual understanding and resourcefulness of the participants in transposing the conception of new pedagogical possibilities into their teaching practices. The observed results allow us to indicate that the course proposal was successful, with most of the group (80%) showing a change in the level of understanding of the concepts of intelligent ecosystems, cooperative learning and pedagogical architectures. We emphasize that of the 10 students, only one of them had a brief previous experience with the Thesis Debate architecture.

The two students who did not change their level showed, during the Seminar, less interest in the area of education. Unlike the other subjects, they still do not carry out teaching activities, remaining in programming activities. One of them is still in preparation for the master’s selection, having attended the Seminar as a special student.

6 Final considerations

The search for transformations in education requires that students experiment with new training proposals, which place them as protagonists of their learning, while they can integrate cooperative learning networks. For this to happen, teachers will need to implement the transformations they advocate in their pedagogical practices, thus achieving practices that are more reflective and articulated with reality.

Considering this idea, the theoretical-methodological proposal of the seminar Intelligent Ecosystems to Support Cooperative Learning was conceived and implemented, assuming the presuppositions of the ecological conception of learning. The work carried out proved to have encouraged transformations in the students' conceptions and pedagogical practices (teachers in training). However, due to the limited time of the Seminar, it is not possible to assess the extent of the impact of the pedagogical proposals experienced and reflected on, leaving open the possibility of continuing the study, by monitoring the students in their teaching spaces.

7 References

Aguilar, J., & Valdiviezo, J. C. P. (2015). A smart learning environment based on cloud learning. International Journal of Advanced Information Science and Technology, v. 39, p. 39–52, 2015.

Bateson, G. (1972). Steps to an ecology of mind. Chandler Pub. Co.

Brighente, M. F., & Mesquida, P. Paulo Freire: from denunciation of a banking education to the announcement of a liberating pedagogy, in Pro-Posições | v. 27, n. 1 (79) | p. 155-177 | jan./abr. 2016.

Brown, J. S. (2000). Growing up: Digital: How the web changes work, education, and the ways people learn. Change: The magazine of higher learning, 32(2):11–20.

Freire, P., & Faundez, A. (2012). Por uma pedagogia da pergunta, Editora Paz e Terra.

García-Holgado, A.; & García-Peñalvo, F. J. (2017). A metamodel proposal for developing learning ecosystems. In: SPRINGER. International Conference on Learning and Collaboration Technologies. [S.l.], 2017. p. 100–109.

Jackson, N.J. (2013). The Concept of Learning Ecologies. In CHAPTER A5 Lifewide Learning, Education & Personal Developmente-book. Disponível em: http://www.normanjackson.co.uk/uploads/1/0/8/4/10842717/chapter_a5.pdf

La Talle, Y ; Kohl de Oliveira, Marta; & Dantas, Heloysa. (2019). Piaget, Vygotsky, Wallon: teorias psicogenéticas em discussão. Summus Editorial.

Lèvy, P. (1990). As tecnologias da inteligência: o futuro do pensamento na era da informática .1. ed. Lisboa.

Menezes, C. S.; Aragón, R. (2018). Pedagogical Architectures for Active Learning. In: Proceedings of PAEE/ALE 2018, Brasília.

Parrat-Dyan, S. (2007) A discussão como ferramenta para o processo de socialização e para a construção do pensamento. .SciELO - Scientific Electronic Library Online. Acesso em 23/04/2023. https://www.scielo.br/j/edur/a/k7GGYYPycJj7ZFDcKtvnBjc/abstract/?lang=pt

Piaget, J. (1972). Epistemologia Genética, WMF Martins Fontes.

Piaget, J. (1978). A tomada de consciência. Edições Melhoramentos.

Polya, G. (1978). A arte de resolver problemas, Editora Interciência, 1978.

Pozo, J.I., Perez, M.P., Dominguez, J., Gomez, M. A., & Postigo, Y. (1994). La Solución de Problemas, Editorial Santillana, Madrid.

Ramozzi-Chiarottino, Zélia. (1988) Psicologia e a epistemologia genetica de Jean Piaget. . Sao Paulo: Epu.

Richardson, A. (2002). An ecology of learning and the role of elearning in the learningenvironment.Global Summit of Online Knowledge Networks, 47:51.

Silveira, P. D. , Cury, D. ; Menezes, C. S. (2022). A framework for designing applications to support knowledge construction on learning ecosystems. In Interaction Design And Architectures , v. 1, p. 158-178.

Silveira, P. D. N. (2022). Um framework conceitual para a concepção de ecossistemas inteligentes de aprendizagem, Tese de Doutorado, Programa de Pós-graduação em Informática (PPGI/UFES).

Silveira, P. D. N., Cury, D. and de Menezes, C. S. (2020). Um framework para concepção de smart learning environments. RENOTE, 18(2):21–30.

Silveira, P. D. N.; Cury, D.; Menezes, C. (2019). Superando fronteiras da educação com ecossistemas de aprendizagem. In: Brazilian Symposium on Computers in Education (Simpósio Brasileiro de Informática na Educação-SBIE). [S.l.: s.n.], v. 30, n. 1, p. 209.

Spector, J. M. (2016). Smart learning environments: Concepts and issues. InSociety forInformation Technology & teacher education international conference, pages 2728–2737. Association for the Advancement of Computing in Education (AACE).

Silva, F. X. et al. (2020) Evaluation of the Knowledge Construction Process in the application of the Pedagogical architecture "Debate of Thesis", IEEE LACLO Conference, Lima-Peru.

Yin, R. (2015) Estudo de caso: planejamento e métodos. 5ª ed. Porto Alegre: Bookman.

Insights into the Levels of Maturity of Brazilian Engineering Education Research: An Analysis of COBENGE's Post-Pandemic Active Learning Papers

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Abstract

The Brazilian Congress on Engineering Education (COBENGE) is the main engineering education event in Brazil and, having passed its 50th edition, it is a fact that the set of its publications over half a century is an important reference source for engineering education in this country. This research work analyzes the levels of maturity in engineering education research in COBENGE 2022 papers and its main objective is to evaluate the nature of the pedagogical interventions reported in these papers and to ascertain the influence of the COVID-19 pandemic on the development of these pedagogical interventions. A study conducted on papers published in COBENGE 2015, whose theme was "Active Learning: Collaborative Engineers for a Competitive World", identified that 50% of the papers published on active learning only described practices or procedures without effectively demonstrating learning gains. The same kind of study on papers published in COBENGE 2022, showed that this percentage dropped to 39%. However, this 11% difference does not translate into papers with a higher level of maturity in engineering education research. These results indicate that it is essential to produce instructional material and create mechanisms and spaces for training and discussion so that Brazilian engineering professors, and COBENGE participants, can develop more pedagogical interventions at levels of greater maturity in engineering education research. Regarding the influence of the COVID-19 pandemic on the development of pedagogical interventions presented at COBENGE 2022, it can be highlighted the concern of engineering professors in using platforms, tools and software in the public domain to prevent some students from being excluded from the teaching and learning processes, and the fact that some researchers have pointed out that active learning strategies and methods have turned remote classes into more meaningful learning experiences than their face-to-face classes.

Keywords: Active Learning; Engineering Education; Engineering Education Research; COVID-19 pandemic.

1 Introduction

Engineering education is extremely important to ensure that professionals in the field have the necessary skills and knowledge to face the complex challenges that arise in industry, society and the world (Broo et al., 2022; Gutierrez-Bucheli et al., 2022; Van den Beemt et al., 2020; Graham, 2018; Jang, 2016; Crawley et al., 2014; Johri, & Olds, 2011). Engineering is a very broad area of knowledge that encompasses several other areas, such as Natural Sciences, Mathematics, Computing, technologies and design, and needs the support of Human Sciences and Social Sciences. Thus, engineering education must encompass these areas in a comprehensive and integrated way so that the training of engineers is truly holistic.

On the other hand, research in engineering education is equally important because it helps to understand how students learn and how engineering education can be improved (Nguyen et al., 2021; Brunhaver et al., 2017; Johri & Olds, 2014; Lohmann, & Froyd, 2014). Research in engineering education can help identify the best pedagogical practices for teaching engineering (Kolmos et al., 2021; Andrews et al., 2020; Felder et al., 2014; Ihsen et al., 2010), evaluate the effectiveness of different teaching and learning strategies and methods (Jamison et al., 2022; Karabulut-Ilgu et al., 2018; Borrego, & Henderson, 2014) and identify areas where engineering education can be improved (Hunsu et al., 2021; Streveler et al., 2016). Engineering education research can also help identify the skills and competencies that engineers need to succeed in their careers, as well as the lifelong learning needs of engineers to stay current with changes in technology and industry (Craps et al., 2022; Chance et al, 2021; Kolmos, & Holgaard, 2019; Passow, & Passow, 2017; Venkatachalam, & Lichtenstein, 2017). In addition, engineering education research can help promote diversity and inclusion in engineering by identifying the barriers that prevent certain groups of students from engaging and succeeding in the field, and developing strategies to overcome these barriers (Ong, Jaumot-Pascual, & Ko, 2020; Simmons, & Lord, 2019; Delaine et al., 2016). In summary, engineering education and engineering education research are extremely important to ensure that engineers have the necessary skills and knowledge to meet the challenges of today's world and to ensure that the engineering continues to evolve and adapt to the needs of society. And as well presented by Edström (2017), the two main objectives of research in engineering education, to seek new knowledge and to contribute to improving engineering education, need not be incompatible.

Recently, the COVID-19 pandemic has had a major impact on engineering education worldwide (McIntyre et al., 2023; Danowitz, & Beddoes, 2022; Delen, & Yuksel, 2022; Krishnakumar, et al., 2022; Casper et al., 2022). With the closure of schools and universities, many engineering schools had to switch to online teaching. Although this was a necessary solution to ensure the safety of students and professors, many challenges arose with the transition to online teaching, such as the unpreparedness of professors for teaching online, the difficulty in maintaining interaction and collaboration between students and professors, and the need to adjust course content for the digital environment. In Brazil, and probably in many other countries, many engineering students also faced problems such as lack of access to the internet and adequate technologies to follow classes.

With the restrictions imposed by the COVID-19 pandemic, another consequence was the drastic decrease in laboratory practices, as many of these spaces were closed or operated at reduced capacity, interrupting students' practical learning. In some engineering schools, the pandemic has also caused delays and changes in curriculum development. Some courses were postponed or cancelled, while others were modified to suit the virtual environment. On the other hand, it is important to emphasize that in a considerable number of engineering schools, professors were able to adapt quickly and find creative solutions to minimize the impacts of the pandemic. This includes implementing advanced remote learning technologies such as online lab simulations and utilizing active learning strategies and methods suitable for online teaching. Furthermore, in some contexts, the COVID-19 pandemic has also had a negative impact on engineering education research. Unfortunately, most professors failed to see the misfortune of the pandemic as an opportunity to study the challenges and new pedagogical practices that were imposed on them. And this can be observed in papers presented at some engineering education conferences, in this “post-pandemic” period. An example to be cited is the Brazilian Congress of Engineering Education (COBENGE), which is considered the most important forum for reflection on engineering education in Brazil. The event is annually promoted by the Brazilian Association of Engineering Education (ABENGE), with the aim of bringing together schools and professors to, cooperatively with government agencies and other entities interested in engineering education, share experiences, promote debates, and propose strategies to train professionals increasingly more qualified and able to meet the needs of the country.

Thus, considering all the challenges faced by the engineering education community in Brazil and around the world in 2020 and 2021, the most critical period of the COVID-19 pandemic, this research work has the main objective of evaluating the nature of the pedagogical interventions reported in papers on active learning presented at COBENGE 2022 and to investigate the influence of the pandemic on the development of these pedagogical interventions. Sixty one papers presented in this edition of COBENGE, and that were related to active learning, were analyzed to determine whether they are papers that address interventions such as experience reports (ER), effective teaching (ET), scholarly teaching (ST), a scholarship of teaching and learning

(SoLT) or if they are engineering education research (EER) papers, and if good teaching practices were presented to minimize the impacts of the pandemic on engineering education through active learning.

Next, the following topics are developed in this research paper: a brief explanation on the levels of maturity of engineering education research; the research methodology employed; the analysis of the results obtained; and some final considerations.

2 The progressive levels of maturity of EER

It is important to point out that research in engineering education starts with experiences of effective teaching (ET) and as the research becomes more mature, it progresses to scholarly teaching (ST), scholarship of teaching and learning (SoLT) and engineering education research (EER). In other words, it can be considered that ET, ST and SoTL are progressive levels of maturity of EER. In a research study previously carried out with papers from COBENGE 2015, Viana and Villas-Boas (2022) added another level of maturity defined as the experience report (ER) interventions, since a large number of the papers analyzed were at a level less “mature” than that of papers belonging to the ET level.

The maturity levels of research in engineering education and their main characteristics can be seen in Figure 1.

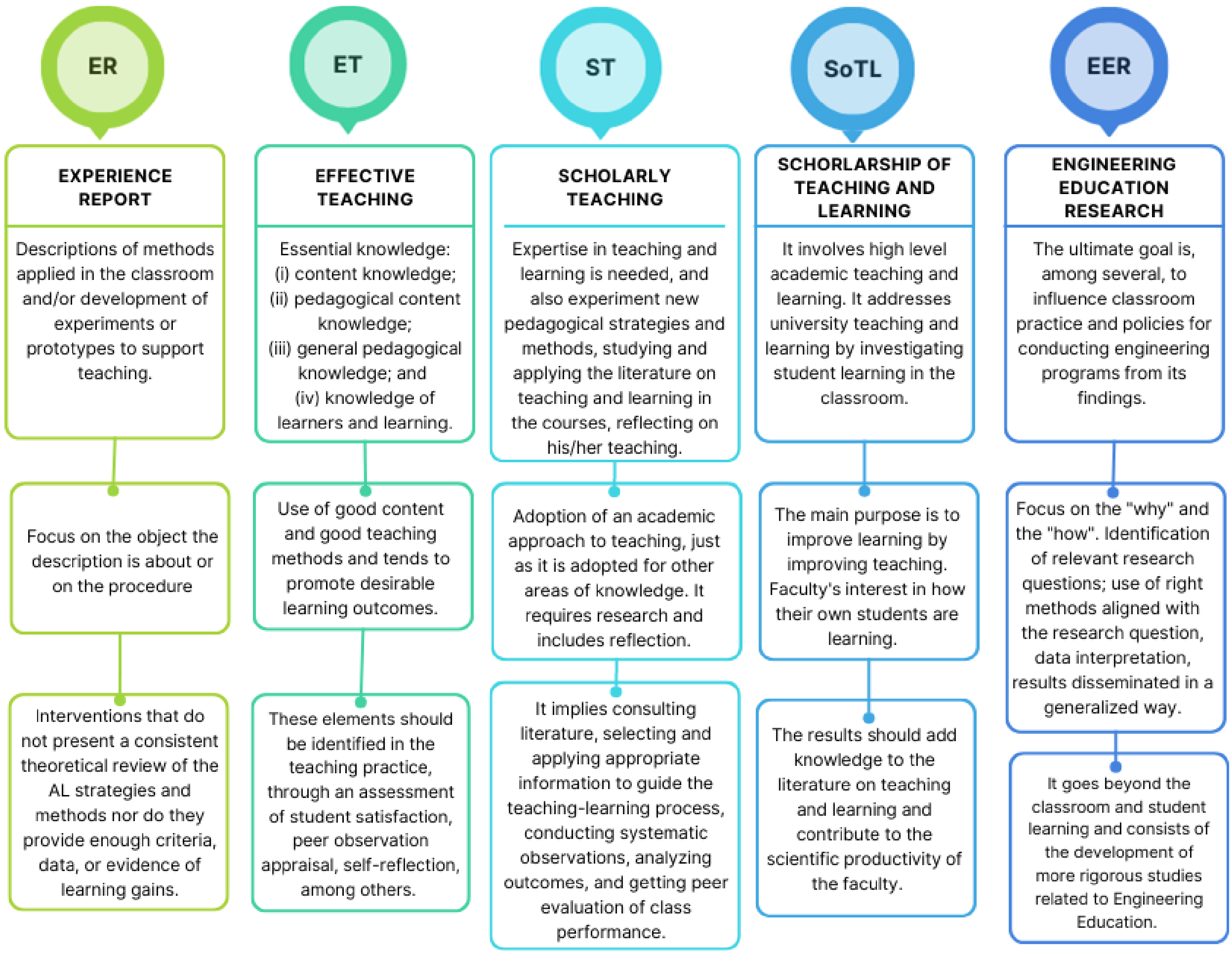

Figure 1. Progressive levels of maturity of EER according to Viana & Villas-Boas (2022).

Having presented the main characteristics related to the levels of maturity of engineering education research in Figure 1, the next section will address the methodological procedures developed in this research.

3 Methodological Procedures

The present research is characterized as qualitative research. It investigates the nature of papers presented at COBENGE 2022, regarding the classification of these papers as being pedagogical interventions, such as ER, ET, ST, SoTL, or research in engineering education (EER). The qualitative character of this research is explained by Deslauriers (1991, p. 58) when he says that "The purpose of the sample is to produce in-depth and illustrative information: whether it is small or large, what matters is that it is capable of producing new information."

The survey, which identified the 61 studies involving active learning strategies and methods published in the proceedings of COBENGE 2022 and analyzed in this research, was carried out using the same set of keywords that were used by Pinto et al. (2020) in a paper whose objective was to verify the growth of active learning in engineering education in Brazil in the period from 2007 to 2019 in COBENGE's proceedings.

After identifying the papers, their abstracts were read for an initial classification in terms of ER, ET, ST, SoTL, and EER. Subsequently, a more in-depth reading of each of the papers was necessary for the final classification presented in this paper. For classification into ER, ET, ST, SoTL or EER, the characteristics described in Figure 1 of section 2 were considered. The researchers randomly divided the 61 papers into two groups and analyzed 30 and 31 papers, respectively. In case of doubt, the paper was read by the other researcher, and this second reading was followed by a discussion between the two researchers. The characteristics presented in Figure 1 were sought in each of the papers. When found in the papers, these characteristics were highlighted and noted.

In addition, it was also investigated in the 61 papers related to active learning, reports of the influence of the COVID-19 pandemic on their development. In these papers, it was sought to find creative pedagogical practices to minimize the impacts of the pandemic, in particular, the use of active learning strategies and methods suitable for online teaching. The implementation of advanced remote learning technologies was also taken into account, such as online laboratory simulations, software and digital tools, whose objective was to enhance remote active learning environments. In the next section, the results obtained through the described procedures are presented and discussed.

4 Results and Discussion

Figure 2 shows the number of papers and the respective percentage related to the total number for COBENGE 2022 active learning related papers, classified in each of the levels, namely ER, ET, ST, SoTL or EER.

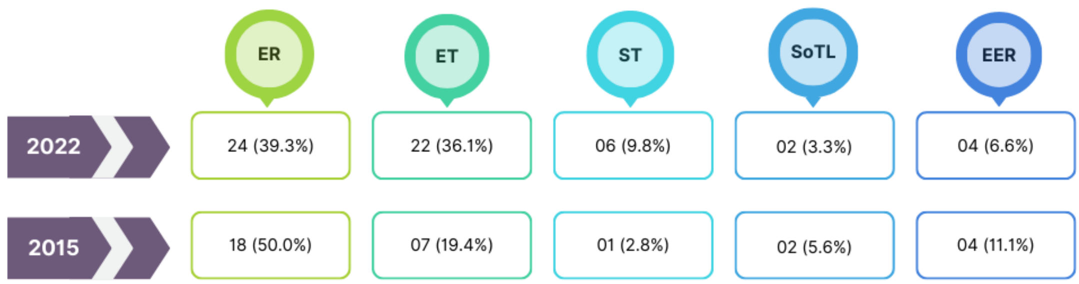

Figure 2. Classification of papers according to levels of maturity of EER.

The general analysis of the classification for COBENGE 2022 active learning related papers shows an imbalance between the quantity of ER and ET papers, 75.4% of the total number of papers, and scientific research papers, which include the ST, SoTL and EER levels, and represent 19.7% of the total number of papers analyzed. In addition, 4.9% of the papers do not fall into any of the levels. In Figure 2, the results for the same type of analysis performed with articles from COBENGE 2015 (Viana & Villas-Boas, 2020) can also be seen. In the COBENGE 2015 case, the general analysis of the classification also shows an imbalance between the quantity of ER and ET papers, 69.4% of the total number of papers, and scientific research papers, which include the ST, SoTL and EER levels, and represent 19.4% of the total number of papers analyzed. In 2015, 11.1% of the papers related to active learning do not fall into any of the levels of maturity of EER.

It is worth highlighting the increase in publications characterized as effective teaching (ET), which in 2015 represented 19.4% of the active learning papers and, in 2022, represented 36.1%. This fact demonstrates a concern with teaching practice, through the evaluation of learning outcomes and reflection on the methods practiced. This concern was also reflected with the increase in the number of papers characterized as scholarly teaching (ST), although on a smaller scale.

The most relevant results for each level of COBENGE 2022 active learning related papers are presented and discussed below.

4.1 ER

The percentage of papers classified as experiment report (ER) was 39.3%, which still represents a significant amount of the total number of active learning papers, for this reason it is important to explore a little more the characteristics of these papers to find means that allow the authors to improve their proposals and the evaluators to qualify more precisely the papers submitted to COBENGE. In addition to the aspects mentioned in Figure 1, some papers also drew attention for the following reasons: they mentioned the use of active learning strategies and methods but did not present the procedure used in their application; absence of references to important concepts about the active learning strategies and methods used; incorrect designations about the active learning strategies and methods used; and the need for a better systematization of the paper structure.

As for the active learning strategies and methods that appeared in the papers at this level of maturity, they can be separated into five types: (i) PjBL and PBL, with five papers; (ii) hands-on, maker movement, experimentation, STEM and STEAM, with 12 papers; (iii) projects in general (integrative, interdisciplinary and other denominations), with five papers, (iv) flipped classroom, with two papers and; (v) others, with two papers on different themes (Gamification and Peerwise).

4.2 ET

Twenty two papers were identified with the level of maturity classified as effective teaching (ET). In this research, it is considered that papers of this level of maturity, despite not meeting the criteria of academic research, may indicate a potential for this. The papers classified here as ET, in general, refer to strategies and methods applied in a course or laboratory classes, and include a simple theoretical review on active learning strategies and methods, often in the introduction. The methodology section presents the procedures for implementing the activity and, in the results section, these papers present results from student satisfaction questionnaires and/or their perception of their learning gains. To reach an ST level of maturity, a more consistent theoretical review of active learning strategies and methods used would be necessary and, in addition to student satisfaction questionnaires, the use of other indicators that could demonstrate learning gains, as well as teacher reflection on his/her teaching.

As for the active learning strategies and methods identified in the analysed papers, it can be mentioned (i) PjBL and PBL, with 5 papers; (ii) hands-on, maker movement, experimentation, STEM and STEAM, with 10 papers; (iii) projects in general (integrative, interdisciplinary and other denominations), with 4 papers, (iv) flipped classroom, with 5 papers; and (v) others, with 7 papers on different themes (Debate, CDIO, Design Thinking, Gamification); some papers were counted more than once.

4.3 ST

The six papers classified as scholarly teaching (ST) have as general characteristics a more consistent theoretical review of the active learning strategies and methods, the presence of indicators of student learning gains in addition to satisfaction questionnaires, an analysis of the teaching and learning outcomes in relation to the implemented methods and strategies, and a reflection of the teacher in relation to his/her teaching practice.

Active learning strategies and methods identified in these papers are: (i) PjBL and PBL, in three papers; (ii) hands-on, in two papers; (iii) research-based learning, in one paper.

4.4 SoTL

At the SoTL level, two papers were identified. This level of maturity encompasses well-conceived and executed research, which includes a good description of methodological procedures, appropriate data collection and analysis, also involves investigating student learning in the classroom, and systematic, evidence-based study of students' learning. Requires knowledge of subject content; of effective and subject-specific pedagogical practices and, in general, involves the professor's collaboration with disciplinary or interdisciplinary colleagues.

An important issue to be considered in SoTL interventions is the focus on improving teaching and learning and contributing to faculty productivity. "Thus, works of this nature are closely related to the existence of faculty training programs" (Viana and Villas Boas, 2022, p. 58-59). In one of the analyzed papers, although the application was carried out in a single class, it is a subject common to several engineering programs, Basic and Experimental Chemistry, thus, the impact of the research in multiple programs is considered. In the second analyzed paper, a survey of the evidence on the problems and solutions found in the teaching of classical thermodynamics is carried out to improve the teaching and learning processes in courses that have topics of this subject in syllabus contents. It is observed that in both cases, collaboration and involvement with disciplinary colleagues were essential to ensure relevant and applicable results.

4.5 EER

In the EER level, where the studies are supposed to go beyond the classroom and student learning and consists of the development of more rigorous studies related to engineering education, four papers were identified. As with the SoTL maturity level, more rigorous research is required, which includes a comprehensive and rigorous literature review, to build on existing knowledge and contribute to the advancement of the research field. The evaluated papers present more judicious methodological procedures, data collection and analysis. They do not necessarily deal with student learning, but from the bibliographic research and theoretical review and/or evidence-based systematic study, as a result, they present an overview of the research field and/or proposals of models and frameworks. It is worth noting, however, the absence of validation or application of the proposals, which is important for the generalization of the results.

4.6 Good teaching practices in active learning to mitigate the impacts of the COVID-19 pandemic

Of the 61 papers related to active learning and studied in this research, 34 do not mention the pandemic. Some were held before the pandemic (until 2019), others after (from 2022), and still others, even though they were held during the pandemic, make no mention of the pandemic event. Of the 28 papers that mention the pandemic event, 26 explicitly mention that the classes were held remotely, and the other two papers, considering the content of text, it is inferred that they had classes in the remote format. Still out of the 28 papers, six papers explicitly mention tasks performed in asynchronous moments and, once again, it is possible to infer that the remaining 22 papers also had several activities taking place asynchronously.

Regarding the classification of the 28 papers according to the maturity levels of engineering education research, eight are ER papers, 15 are ET papers, three are ST papers, one paper is SoTL and one paper does not fit any of the levels.

With regard to the use of active learning strategies and methods, there are explicit mentions for the use of flipped classroom (nine papers), gamification (seven papers), problem-based learning (six papers), project-based learning (six papers), team-based learning (two papers), game-based learning (one paper), case studies (one paper), design thinking (one paper), notebook-based learning (one paper), and remote labs and hands-on activities (seven papers). Five papers mention the production of videos to assist in the implementation of the flipped classroom and in the development of remote laboratories.

Among the 28 papers that mention the pandemic event, there are records of the use of different platforms (Discord, Zoom, Google for Education, Google Meet, Youtube, Genially, Beecrowd, social networks), virtual learning environments, and resources and tools (Mentimeter, Google Forms, Jamboard, Google Slides, Google Spreadsheets, Trello, Revit, PeerWise).

As for the papers that present good teaching practices to minimize the impacts of the pandemic through active learning, it is worth highlighting two papers whose authors are very concerned about using platforms, tools and software in the public domain to prevent some students from ending up excluded from teaching and learning processes: (i) classified as ET, the paper by Almeida et al. (2022) presents a remote laboratory initiative that was implemented using the Internet of Things (IoT) in order to bring to professors and students the sense of practical classes, hands-on immersion, experimentation, and collection of results. Digital collaborative notebooks were adopted. Alternatives were sought for an intelligent notebook, which is the virtual notebook, where students collaborate in an integrated environment to organize the problem in terms of figures and texts, present the rationale for the solution, the artifacts built in the form of codes (and circuits) and the results of activities and tests, all centralized in this environment; (ii) also classified as ET, the paper by Celestino et al. (2022) presents activities carried out on the Discord platform, which, in addition to being accessible on any device connected to the internet, was relatively popular among students in the age group served by the course. Through the creation of channels intended both for accessing the materials and video lessons prepared by the institution's students and for carrying out doubt clearing sessions and synchronous classes, Discord satisfactorily met the demands of the course's pedagogical practices, allowing students to create study rooms, groups for discussions on gamification issues and spaces for leisure. The Beecrowd platform was also used, which allowed students who did not have a computer to use in the course to access and execute the problems by cell phone, using the device's own browser to do so.

Finally, it should be noted that many of the papers pointed out that active learning strategies and methods transformed remote classes into more meaningful learning experiences. In particular, the paper by Shayani (2022), classified as ET, highlighted that the methodology, which had already been used for some years before the pandemic, was enhanced by remote teaching because, when considering student-centered education, it proved to be directly compatible with both synchronous and asynchronous activities.

5 Final Remarks

In 2015, the 43rd edition of COBENGE had the theme “Active Learning: Collaborative Engineers for a Competitive World”. At that time, 379 papers were published, almost 10% of which were about active learning. With the impact of the COVID-19 pandemic, there was a drop in the number of publications in COBENGE and, in 2022, there were 258 papers published, with more than 20% on active learning. Thus, even with the decrease in the total number of the conference papers, the percentage related to active learning doubled from 2015 to 2022. However, this increase did not imply the presentation of a greater number of scientific research papers, which include the ST, SoTL and EER levels. In 2015, papers classified as ER and ET added up to 69% of the total number of papers related to active learning and, in 2022, the quantity of ER and ET papers was 75.4% of the total number of papers, that is, it can be said that the percentage changed little. However, it is observed that the percentage of active learning papers classified as ER decreased from 50% in 2015 to around 39% in 2022. Although there was a reduction in the percentage of papers with the lowest level of EER maturity, from 2015 to 2022, again, the difference did not translate into scientific research papers, which include the ST, SoTL and EER levels.

At the international level, conferences such as ASEE[2] and SEFI[3] are good forums for researchers to present initial stages or partial results of their research in engineering education. It is observed that many of the papers presented at these conferences do not present all the results of the research, as they keep these "unpublished" results to be published in high-impact journals in the area. In the case of the few EER articles analyzed in this research, it can be said that the same occurs. Authors present partial results of their research and then submit the complete research work to a journal with a higher classification by CAPES[4]. One of the actions the authors of this paper intend to undertake is to encourage the participation of more Brazilian and foreign researchers in COBENGE with papers at the ST, SoTL and EER levels. Unfortunately, perhaps one of the reasons why the number of papers in COBENGE remains small, and their level of maturity is still a little distant from ST, SoTL and EER, is precisely because the event does not have its proceedings indexed in any database recognized by national and international assessment bodies.

Regarding the influence of the COVID-19 pandemic on the development of pedagogical interventions presented at COBENGE 2022, it can be said that 46% of papers related to active learning mention the pandemic event and present creative solutions to minimize the impacts of the pandemic, in particular the use of active learning strategies and methods suitable for remote teaching. Some papers also present the implementation of advanced remote learning technologies, such as online laboratory simulations, software and digital tools. But, the most important thing to emphasize about these papers is the concern of engineering professors in using platforms, tools and software in the public domain to prevent some students from ending up excluded from the teaching and learning processes, and the fact that some researchers pointed out that active learning strategies and methods transformed remote classes into more meaningful learning experiences than their face-to-face classes, as students found themselves challenged by a definitively student-centered education, forced by synchronous and asynchronous teaching and learning activities.

Finally, the results of this research and of previous studies (Viana & Villas-Boas, 2022; Pinto et al., 2020) suggest that some effort should be made to help Brazilian engineering professors starting with research in engineering education to present their results at COBENGE. The professor could begin with effective teaching (ET) experiences and, as research becomes more mature and he/she feels more secure in his/her reflective practice, the research could progress to ST, SoTL and EER. It is essential to produce attractive instructional material that is easy to “consume” and create mechanisms and spaces for teacher training and discussion so that COBENGE participants can develop more pedagogical interventions that are at least at the ET level or at higher EER maturity levels.

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[2] ASEE is the American Society for Engineering Education

[3] SEFI is the European Society for Engineering Education

[4] CAPES is the Brazilian Higher Education Personnel Improvement Coordination Foundation

6 References

Almeida, F. V., Hayashi, V. T., Arakaki, R., Midorikawa, E. T., & Cugnasca, P. S. (2022). Notebook Based Learning (NBL): Aplicação de notebooks no processo de aprendizagem. In *L Congresso Brasileiro de Educação em Engenharia e V Simpósio Internacional de Educação em Engenharia da ABENGE "A Arte da Formação em Engenharia para os desafios do Desenvolvimento Sustentável"* ABENGE. DOI: 10.37702/2175-957X.COBENGE.2022.3966

Andrews, M. E., Graham, M., Prince, M., Borrego, M., Finelli, C. J., & Husman, J. (2020). Student resistance to active learning: do instructors (mostly) get it wrong? *Australasian Journal of Engineering Education*, *25*(2), 142-154.

Borrego, M., & Henderson, C. (2014). Increasing the use of evidence-based teaching in STEM higher education: A comparison of eight change strategies. *Journal of Engineering Education*, *103*(2), 220-252.

Broo, D. G., Kaynak, O., & Sait, S. M. (2022). Rethinking engineering education at the age of industry 5.0. *Journal of Industrial Information Integration*, *25*, 100311.

Brunhaver, S. R., Korte, R. F., Barley, S. R., & Sheppard, S. D. (2017). Bridging the gaps between engineering education and practice. In *US engineering in a global economy* (pp. 129-163). University of Chicago Press.

Casper, A. A., Rambo-Hernandez, K. E., Park, S., & Atadero, R. A. (2022). The impact of emergency remote learning on students in engineering and computer science in the United States: An analysis of four universities. *Journal of Engineering Education*, *111*(3), 703-728.

Celestino, C. C., Baroni, L., Fazzolari, H. A., Fernandes, G., & Castro-Filho, D. (2022). Com Ambiente Virtual De Aprendizagem ativa. In *L Congresso Brasileiro de Educação em Engenharia e V Simpósio Internacional de Educação em Engenharia da ABENGE "A Arte da Formação em Engenharia para os desafios do Desenvolvimento Sustentável"* ABENGE. DOI: 10.37702/2175-957X.COBENGE.2022.3841

Chance, S., Lawlor, R., Direito, I., & Mitchell, J. (2021). Above and beyond: ethics and responsibility in civil engineering. *Australasian Journal of Engineering Education*, *26*(1), 93-116.

Craps, S., Pinxten, M., Knipprath, H., & Langie, G. (2022). Different roles, different demands. A competency-based professional roles model for early career engineers, validated in industry and higher education. *European Journal of Engineering Education*, *47*(1), 144-163.

Crawley E. F., Malmqvist J., Östlund S., Brodeur D. R., Edström K. (2014) *Rethinking Engineering Education: The CDIO Approach* (2nd ed.). Springer.

Danowitz, A., & Beddoes, K. (2022). How the COVID-19 pandemic reshaped demographic variation in mental health among diverse engineering student populations. *Australasian Journal of Engineering Education*, *27*(2), 67-76.

Delaine, D. A., Williams, D. N., Sigamoney, R., & Tull, R. G. (2016). Global Diversity and Inclusion in Engineering Education: Developing Platforms toward Global Alignment. International Journal of Engineering Pedagogy, *6*(1), 56-71.

Delen, I., & Yuksel, T. (2022). Abrupt Shift or Caught Off Guard: A Systematic Review of K-12 Engineering and STEM Education's Response to the COVID-19 Pandemic. *Journal of Pre-College Engineering Education Research (J-PEER)*, *12*(2), Article 6, 108–120.

Edström, K. (2017). The role of CDIO in engineering education research: Combining usefulness and scholarliness. *European Journal of Engineering Education*, *45*(1), 113-127.

Felder, R. M., Brent, R., & Prince, M. J. Engineering Instructional Development: Programs, Best Practices, and Recommendations. (2014). In Johri, A., & Olds, B. M. (Eds.). *Cambridge handbook of engineering education research*. (pp. 503-536). Cambridge University Press.

Graham, R. (2018). The global state of the art in engineering education. *Massachusetts Institute of Technology (MIT) Report,* Massachusetts, USA.

Gutierrez-Bucheli, L., Kidman, G., & Reid, A. (2022). Sustainability in engineering education: A review of learning outcomes. *Journal of Cleaner Production*, *330*, Jan 2022, 129734.

Hunsu, N. J., Carnell, P. H., & Sochacka, N. W. (2021). Resilience theory and research in engineering education: what good can it do? *European Journal of Engineering Education*, *46*(6), 1026-1042.

Ihsen, S., Jesiek, B. K., Kammasch, G., & Beddoes, K. (2010). Diversity of didactical approaches to foster diversity of engineers. In *Joint International IGIP-SEFI Annual Conference, IGIP-SEFI*, Trnava, Slovakia.

Jang, H. (2016). Identifying 21st century STEM competencies using workplace data. *Journal of science education and technology*, *25*, 284-301.

Johri, A., & Olds, B. M. (2011). Situated engineering learning: Bridging engineering education research and the learning sciences. *Journal of Engineering Education*, *100*(1), 151-185.

Johri, A., & Olds, B. M. (Eds.). (2014). Cambridge handbook of engineering education research. Cambridge University Press.

Karabulut-Ilgu, A., Jaramillo Cherrez, N., & Jahren, C. T. (2018). A systematic review of research on the flipped learning method in engineering education. *British Journal of Educational Technology*, *49*(3), 398-411.

Kolmos, A., & Holgaard, J. E. (2019). Employability in engineering education: Are engineering students ready for work? *The Engineering-Business Nexus: Symbiosis, Tension and Co-Evolution*, 499-520.

Kolmos, A., Bøgelund, P., & Holgaard, J. E. (2021). Inquiry and Learning in Engineering. *International Handbook of Inquiry and Learning*, 345-357.

Krishnakumar, S., Maier, T., Berdanier, C., Ritter, S., McComb, C., & Menold, J. (2022). Using workplace thriving theory to investigate first-year engineering students' abilities to thrive during the transition to online learning due to COVID-19. *Journal of Engineering Education*, *111*(2), 474-493.

Lohmann, J. R., & Froyd, J. E. (2014). The status of research on the teaching and learning of engineering design skills. *Journal of Engineering Education*, *103*(3), 325-370.

Manierre, M. J., DeWaters, J., Rivera, S., & Whalen, M. (2022). An exploration of engineering instructors' pedagogical adaptations early in the COVID-19 pandemic. *Journal of Engineering Education*, *111*(4), 889-911.

McIntyre, B. B., Rohde, J., Clements, H. R., & Godwin, A. (2023). Connection and alienation during the COVID-19 pandemic: The narratives of four engineering students. *Journal of Engineering Education*, *112*(2), 521-541.

Nguyen, K. A., Borrego, M., Finelli, C. J., DeMonbrun, M., Crockett, C., Tharayil, S., ... & Rosenberg, R. (2021). Instructor strategies to aid implementation of active learning: a systematic literature review. *International Journal of STEM Education*, *8*, 1-18.

Ong, M., Jaumot-Pascual, N., & Ko, L. T. (2020). Research literature on women of color in undergraduate engineering education: A systematic thematic synthesis. *Journal of Engineering Education*, *109*(3), 581-615.

Passow, H. J., & Passow, C. H. (2017). What competencies should undergraduate engineering programs emphasize? A systematic review. *Journal of Engineering Education*, *106*(3), 475-526.

Pinto, G. R. P. R., Oliveira, J. A. C. B., Viana, D. M., das Neves, R., & Villas-Boas, V. (2020, April). Work-in-Progress: A Systematic Mapping Study of Experiences with Active Learning Strategies and Methods in Brazilian Engineering Education. In 2020 IEEE Global Engineering Education Conference (EDUCON) (pp. 1819-1823). IEEE.

Shayani, R. A. (2022) Metodologia motivadora de ensino-aprendizagem visando trabalhar competências de engenharia relacionadas ao desenvolvimento sustentável. In *L Congresso Brasileiro de Educação em Engenharia e V Simpósio Internacional de Educação em Engenharia da ABENGE "A Arte da Formação em Engenharia para os desafios do Desenvolvimento Sustentável"* ABENGE. DOI: 10.37702/2175-957X.COBENGE.2022.3930

Shuman, L. J.; Besterfield-Sacre, M. (2019). Innovation through Propagation: Future Directions for Engineering Education Research. *Advances in Engineering Education*, *7*(2), 1-14.

Simmons, D. R., & Lord, S. M. (2019). Removing Invisible Barriers and Changing Mindsets to Improve and Diversify Pathways in Engineering. *Advances in engineering education*, *7*(2), 1-22.

Streveler, R. A., Borrego, M., & Smith, K. A. (2016). International perspectives on engineering education research. *Journal of Engineering Education*, *105*(4), 601-604.

Van den Beemt, A., MacLeod, M., Van der Veen, J., Van de Ven, A., Van Baalen, S., Klaassen, R., & Boon, M. (2020). Interdisciplinary engineering education: A review of vision, teaching, and support. *Journal of engineering education*, *109*(3), 508-555.

Venkatachalam, A., & Lichtenstein, G. (2017). Critical thinking and interdisciplinary engineering education. *Journal of Engineering Education*, *106*(1), 26-45.

Viana, D. M.; Villas-Boas, V. (2022) Do Brazilian Engineering Professors do Engineering Education Research in Active Learning? A Case Study. International Symposium on Project Approaches in Engineering Education; Active Learning in Engineering Education Workshop; International Conference on Active Learning in Engineering Education (PAEE/ALE'2022), Alicante - Spain, 06 -08 July 2022. DOI: 10.5281/zenodo.6924254

Applied teaching methodologies and practices in the development of the Final Course Paper (TCC) in engineering at FCA – Unicamp

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Abstract

This work presents the implementation process and the methodology used in the Final Course Paper (TCC) for the Manufacturing Engineering and Production Engineering courses at the Faculty of Applied Sciences at Unicamp. The implementation of this methodology began in 2015 and from 2017 onwards, each TCC project consists of solving a real problem presented by a local company associated to the Confederation of Companies of the State of São Paulo - Limeira. The relationship in promoting an environment of real problems through a business class entity is a pioneer in Brazil. So far, 55 different projects have been developed, in 25 companies located in the region of Limeira, SP, with the participation of 538 students. The companies present the topics for challenges to the students, who must define the problem to be solved (diagnosis), present a solution, demonstrate its viability and an implementation plan. These projects promote initiatives for improvement by all companies participating in the TCCs, with positive results for both parties.

Keywords: Real engineering problems, Academic extension, CIESP Limeira.

1 Introduction

The Final Course Paper (TCC – Trabalho de Conclusão de Curso in Portuguese) of the Manufacturing Engineering and Production Engineering courses at the Faculty of Applied Sciences (FCA) - Unicamp is a mandatory component and is offered in the form of a discipline in the ninth semester of the respective courses. This discipline is developed during a semester. The student can choose to work in a group, developing a solution to problems proposed by the local industry, or to work individually, developing a traditional TCC monograph. Since 2017, 538 students choose to work with the industry problems and 176 choose to work with traditional TCC monograph. This article aims to present the work developed by FCA engineering courses in TCCs applied in real solutions for industry in the city of Limeira - SP.

The implementation of this work format began in 2015, when the coordinators of the courses at the time were granted an invitation to visit universities in other countries, aiming at learning new methodologies and pedagogical practices for Engineering courses. They visited some institutions in the United States of America, with emphasis on the Georgia Institute of Technology - Georgia Tech and Olin College, where they learned about the application of new teaching methodologies aimed at practices on product development in TCC.

Olin College of Engineering develops a program called Senior Capstone Program in Engineering (SCOPE), where senior students apply their knowledge in a corporate consulting project. Groups of 6 students, mentored by a professor, work for a year on a project proposed by a company. This work model served as the basis for the TCC described in this work.

Students in the Industrial Engineering course at the Georgia Institute of Technology complete their graduation with a course on engineering development design (Senior Design - Georgia Tech). The themes of the projects are proposed by companies and the students work in groups of six to eight members, during a semester, to solve the problem.

European universities also develop course conclusion works with the participation of companies (TUM, Politecnico Milano). As these universities adopt the Bologna Model, the TCC model would be the equivalent of the master thesis of engineering courses. The University of Grenoble (Master in SIE) offers the student the option of developing a work equivalent to the final project (research project) through an internship in a company.

Initially, the topic of TCC was unique to the class and related to product development and manufacturing. Students worked in groups and over four semesters, the format and offering of the TCC was being improved. The search for real themes began in 2017, when the course coordinators sought the Confederation of Industries of the State of São Paulo - CIESP in Limeira to get a communication channel so that the local industry could propose real problems faced by companies. We had the unconditional support of its directors and the regional manager and started a pilot project with three problems from different companies. Since then, the format of the TCC in the Engineering courses at FCA-Unicamp aims to propose solutions to a real problem presented by industries affiliated to CIESP Limeira.

The experience acquired with companies and students in these six years is presented in this work. The work methodology is presented in chapter 2, where we describe the main stages of solving TCC problems. We were able to maintain a direction of work through student presentations in gates during the development of the Final Paper. Such meetings are fundamental to achieve an interaction between students, professors and industry. In chapter 3 we present the main results of our work, such as the number of students involved, which reached 538 students, 25 companies involved and 55 topics developed. It is noteworthy that for each theme we have between 3 and 4 groups proposing different solutions.

2 Methodology

There is a strong and longstanding interest in transforming engineering education from content-based to competency-based learning. In this sense, engineering courses need to train students so that they can conceive, design, implement and operate products and services of high complexity and added value for society in general.

Different methodologies are increasingly established in engineering teaching that allow students to be protagonists, such as Active Learning (AL), Problem Based Learning (PBL) and Project Based Learning (DBL - Design Based Learning). These learning environments allow for great challenges for students, even if they do not demonstrate improvements in student engagement and attitudes (ORTEGON, 2019).

In different studies, projects aimed at teaching engineering encourage not only active methodologies, but concerns in some dimensions, such as sustainable development, from economic, social and environmental aspects, with an increase in the use of technologies (ALHEFHAWI, 2021).

Cooper (1990) proposed a method or technique for the development of new products called Stage-Gate System, which can be translated as a model of product development system through “gates” of passage, as the project evolves. The model derived from combining different conceptual and operational models for management to develop new products and innovative technologies. Figure 1 illustrates the Stage-Gate System model. Originally the Stage-Gate can have from 4 to 7 gates.

Each gate works as an evaluation filter, which, when approved, moves on to the next one, and, on the contrary, remains in rework and revision of the project criteria. Each stage must consider advancing the characteristics and content of each gate. Cooper (1990) considers that the Stage-Gate System model provides a project progress map for product development leaders and participants.

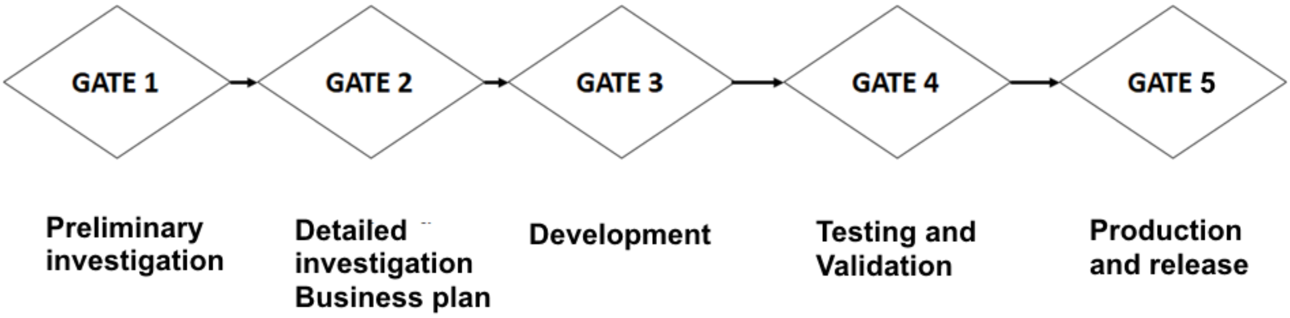

Figure 1. Stage-Gate System Model.

Source: Adapted from Cooper (1990)

2.1 Methodological procedure

Considering the application of learning through challenges and the active participation of students, a methodological procedure was developed for the development of the TCC, consisting of 5 stages: Request for topics by companies affiliated to CIESP, located in Limeira, SP, Brazil; Selection of themes by professors and representatives of companies, Dissemination by seminar to students for dissemination of themes; Distribution of themes to groups of composed students; beginning and development of works throughout one semester, in "gates", as shown in Figure 2.

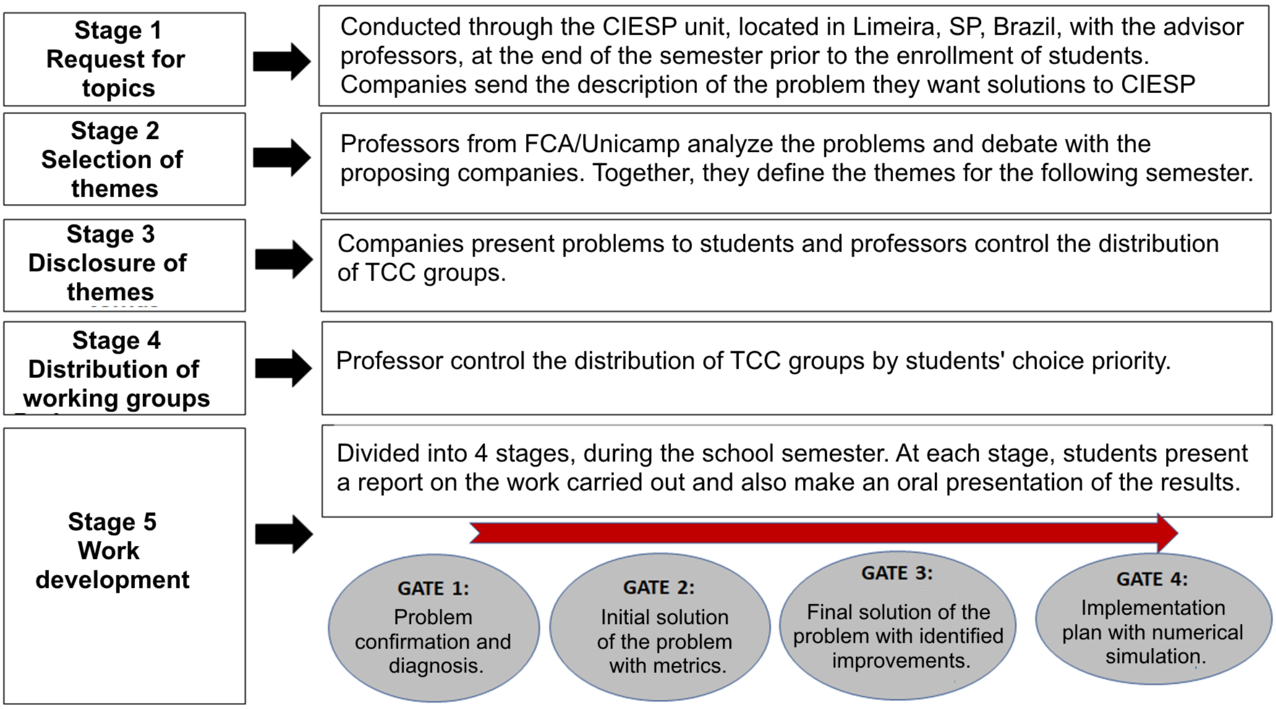

Figure 2: Methodological procedure for developing the TCC

The project is evaluated at each of the gates, by a group of professors and by the companies' engineers. Thus, each project undergoes four assessments. Failing two gates or the final gate disqualifies the project and students fail the discipline.

Project themes are the result of industry interest areas and faculty expertise. The discipline is biannual, so the projects last 4 months. The discussion of the projects starts 2 to 3 months before the beginning of the semester. Ciesp advertises to its members and they get back to us with interested companies. The professors then visit the companies and discussions about the projects begin. The projects are always defined by the companies, thus there is a great variation of problems and scenarios. This step is critical because we need to adjust the theme to the time we have to execute and the resolution capacity of the students of the engineering courses.

The work developed at TCC assisted approximately 500 students in nine semesters, benefiting more than 25 local companies associated to CIESP - Limeira. There were 46 different themes, which encompass the most diverse areas of performance of the production/manufacturing engineer. The themes developed in the area of Manufacturing Engineering are related to the areas of automation (15%), design (33%) and manufacturing process (52%), indicated in Figure 3.

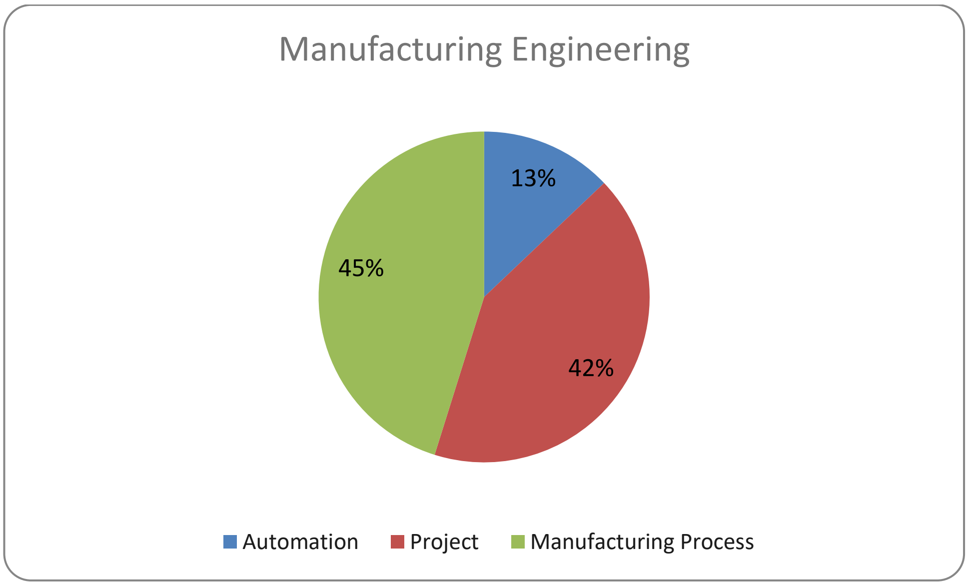

Figure 3 - Distribution of topics in the areas of Manufacturing Engineering

The automation projects used, for the most part, the Arduino platform to implement the prototypes. This choice is justified due to the ease of implementation of prototypes, contact with this hardware during the course in several disciplines, components at affordable prices and availability of a laboratory (LAMADI) in the faculty to support the projects. In addition, there is a vast online material available where students can search for similar information and projects.

Project themes includes the development of machines and numerical simulations. Structural analysis using the Finite Element Method stands out as the tool most used by students. The use of computer simulation is highly encouraged during the course and the application in real cases during the TCC brings great gains in student learning. Some companies are still in the process of implementing this tool and the students' work sought to show the advantages and limitations of this method.

Manufacturing processes is the area with the largest number of topics in Manufacturing Engineering. This is due to the greater number of professors guiding the TCC in this area and the greater identification of students with the respective topics offered by companies. Among the manufacturing processes studied, we can mention micro casting, transition and machining. The students' greater ease in obtaining laboratory test results, sometimes not accessible to companies, was well accepted by the local industry.

With regard to Production Engineering, there is a distribution between factory design/layout (41%), production planning and control (18%), production systems (14%), operational research/supply chain (14%), management of projects (9%) and economic engineering (5%), indicated in Figure 4.

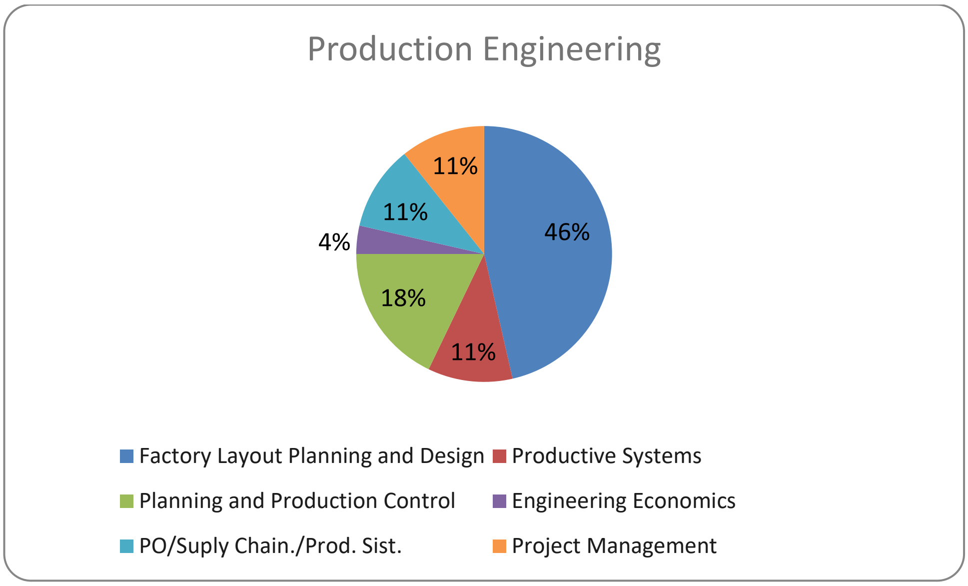

Figure 4 - Distribution of themes in the areas of Production Engineering

The topics related to Production Engineering are in line with the content offered in the course disciplines and are integrated between them.

Work on factory design involved the physical arrangement of machines and transformation equipment, aligned with the mapping of the production flow, through Lean Manufacturing techniques and concepts. The results were satisfactory, with complete implementation of the projects carried out, mainly because the simulations of the proposals demonstrated the results of the proposed improvements.

Projects related to production planning and control were to define production and maintenance scheduling, allowing better use of resources and combination of the best sequencing.

Projects on production systems were aimed at increasing the productivity and effectiveness of operational processes, as indicators of OEE - Overall Effectiveness Equipment.

Projects relating to operational research and supply chain were applied over a combination of operational sequencing such as coil cutting, warehousing, order preparation and picking.

Finally, the projects on economic engineering dealt with the analysis of costs by activities and the feasibility of investments in new productive resources.

These projects involved common techniques on Lean Manufacturing, Six Sigma, mathematical modelling and discrete process simulation.

Offering topics involving the most diverse areas of engineering was only possible due to the collaboration with CIESP - Limeira. The access we had to different companies made such a range of engineering problems possible. The fact that companies take turns offering problems to students guarantees new topics every semester. We also recognize the follow-up work done by engineers and owners to our students. In this way, this alternation of companies allows them to gain a breath to participate in later semesters.

Students need to work with multidisciplinary problems, developing skills necessary for their professional activities with the guidance of professors and receiving support from participating companies. In the vast majority of cases, the students have already had access to the theoretical load and their performance then depends on their behavioural skills in the face of the problem they are facing. In this controlled environment, we achieved a great gain in the student's maturation during the TCC execution process. As a result, 92% of the students completed the TCC work, which was approved by the companies, 5% of the students dropped out of the subject and 3% did not have their work approved.

The commitment between company, student and professor is essential for the development of a good work of TCC. Students need data to solve the problem, companies need to provide such data and teachers need to mediate this relationship when the process does not run smoothly. Recently, due to the Pandemic situation due to Covid-19, the TCCs had to be developed remotely. Adapting to this new scenario brought many difficulties for all participants in the TCC process. The students were not able to go to the companies and some companies were not able to collect enough data for the correct analysis of the problems. We had to make adaptations to the themes and work on the expectations of the companies regarding the results. The results indicated that such changes were effective and we were able to develop 17 themes in this period of Pandemic.

3 Conclusion

The work developed in the TCC of Manufacturing Engineering and Production Engineering at FCA Unicamp has met the demand for training engineers with a more global, humanistic vision and who is able to put into practice the theory seen in the classroom. The number of participating students and companies that collaborated with the work indicate a consolidation of the methodology applied in the TCCs.

Some benefits to the students are that the themes of the projects are relatively broad, and the group of students must initially make a diagnosis of the problem. That is, students understand that real problems do not come with a statement, and that discovering the real problem can be quite difficult. Once the real problem is defined, the student can apply the engineering tools taught in the course disciplines. Many problems are solved not only with technical knowledge, but with socio-emotional skills that they also develop during the course.

The collaboration of course professors in this process was essential for us to be able to address a wide range of topics. The partnership with CIESP - Limeira gave us the opportunity to apply the work methodology started in 2016. The students' effort to work in areas of engineering that they had not yet had direct contact with was essential for us to achieve deliveries that met the demand for the proposed problems.

We also verified the need for student identification in relation to the company and the theme he works on in the TCC. This is probably the main cause of students dropping out of the subject and we need to improve the way of indicating the TCC assignments for each student. In addition, we are working to present the solved cases of TCC problems to mid-term students to encourage them to participate in this work.

4 References

ALHEFNAWI, Mohammed A. M.Assessing the efficacy of online handouts and active lectures in learning outcomes at the engineering undergraduate level. Ain Shams Engineering Journal 12 (2021) 3375–3380. Elsevier. https://doi.org/10.1016/j.asej.2021.02.012.

COOPER, Robert G.. Stage-Gate Systems: A New Tool for Managing New Products. Business Horizons 33(3):44-54. (1990). DOI: 10.1016/0007-6813(90)90040-I

Master Development, Production and Management in Mechanical Engineering. Technical University of Munich. Initial Page. Available in: https://www.mw.tum.de/en/studies/prospective-students/master-development-production-and-management-in-mechanical-engineering/. Accessed in : 2023.

Master of Science. Politecnico di Milano. Pagina inicial. Available in: https://www.mecheng.polimi.it/master-of-science/?lang=en. Accessed in : 2023.

Master in SIE. Universidade de Grenoble. Initial page. Available in: https://genie-industriel.grenoble-inp.fr/en/studies/master-in-sustainable-industrial-engineering-sie#page-presentation. Accessed in : 2023.

ORTEGON, Katherine. Life Cycle Engineering in an Industrial Engineering undergraduate program, from the classroom to the real life of students. 26th CIRP Life Cycle Engineering (LCE) Conference. Procedia CIRP 2212-8271 © 2019 The Authors. Published by Elsevier B.V.

SCOPE. Olin College. Initial page. Available in : https://www.olin.edu/collaborate/scope/. Accessed in : 29 de set. 2021.

Senior Design for Students. Georgia Tech. Initial page. Available in: https://www.isye.gatech.edu/academics/bachelors/current-students/senior-design. Accessed in : 2023.

Experiencing the implementation of Project-based Learning (PBL) curriculum in a Graphic Design Bachelor: goals, challenges and outcomes.

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Abstract

This study aims to present a model for project-based learning curriculum implementation based on a Brazilian experience from a Graphics Design Bachelor program in a Brazilian public university. The pedagogical approach of Project-based Learning (PBL) involves active student learning through problem-solving and hands-on activities. Unlike traditional teaching methods, teachers act as guides for the self-learning process of the students rather than knowledge transmitters. Even with the advantages of this innovative pedagogical approach, PBL implementation in programmes curriculum is not yet common sense in the context of Brazilian bachelor programmes. One reason for the PBL curriculum's non-implementation in Brazilian bachelor programs is the lack of knowledge required of the academic stakeholders for the first implementation steps. The model consists of the systematic steps necessary for knowledge development related to the PBL curriculum implementation. Results obtained from evidence and survey feedback applied to teachers and students involved in the process indicate that curriculum changes are satisfactory for the first moment of the PBL curriculum implementation.

Keywords: Project-based Learning; Graphics Design, Bachelor's Degree; Curriculum Design; Syllabus.

1 Introduction

Projetc-based Learning (PBL) is an instructional strategy focused on students' active and collaborative long-duration learning, promoting their communication improvement, lifelong learning, personal and professional growth, and teamwork skills.

These advantages are possible since PBL resembles real-life projects that shift away from traditional learning strategies focused on teacher-centered and monodisciplinary lessons, isolated in individual steps. (Jones, 2019; Stoicoiu & Cain, 2014)

PBL as an instructional strategy has evident advantages compared to traditional learning strategies. But although it is, PBL has not gone mainstream in Brazilian bachelor programmes. The same happens in the United States of America where roughly 1% only of US schools are committed to teaching with PBL (PBS NewsHour, 2013).

Aldabbus (2018) and Dahlgren et al. (1998) present some aspects that could difficult PBL commitment by schools: a) programs' curriculum has not been designed to be taught by PBL; b) PBL demands more time than other methods of teaching, sometimes delaying the processes of presenting and covering the lessons scheduled; c) teachers' preconceiving beliefs that PBL would create a "mood of chaos" among the students; d) some centraliser students have difficulties to work on collaborative approach for classmate tasks; e) some students did not have access to personal mandatory technologies that could facilitate theses students to recover and achieve sensible information necessary to their full participation.

This related scenario brings some research questions: Could a public traditional-curriculum Vocational Graphic Design program turn a PBL-curriculum Bachelor Graphic Design? How could this shift process happen? What results would be possible to find? From these research questions, the present study aims to present a model for project-based learning curriculum implementation based on a Brazilian experience from a Graphic Design Bachelor program in a Brazilian public university.

This paper is structured into six sections. This introduction presents the aim of the study and its theoretical background. Section two describes the context of the study. Section three presents the methodological steps adopted for the project-based learning curriculum implementation in the Brazilian Bachelor Graphic Design. Research methodology and results from the implementation process are presented and discussed in sections four and five.. The two last sections of the paper present the conclusions and references.

2 Study Context

This section brings the theoretical concepts related to the present research: Project-based Learning (PBL), contextualisation, and characteristics of the bachelor program and its institution.

2.1 Project-based Learning (PBL) in the Graphic Design Programs

Project-Based Learning is a pedagogical student-centred approach inspired by John Dewey's studies where students are actively engaged in their learning process through meaningful projects. According to Fernandes, Alves, and Uébe-Mansur (2021), PBL respects and attends to students' diversity and needs through flexible learning paths. Furthermore, PBL allows the teachers to flexibly adopt a variety of pedagogical methods, regularly assessing the students, the teaching process, and their tutoring. These advantages provide necessary information to the teaching and learning adjustments during the student learning experience, reinforcing students' autonomy and mutual respect.

Despite these advantages, there are few Graphic Design Bachelor PBL syllabus-centered in Brazil. In the North East Brazilian region: the Design Bachelor Program at the Recife campus and Caruaru campus at the Federal University of Pernambuco (n.d.) and the Bachelor Program of Design at the Federal University of Ceará (n.d.). In the South East Brazilian region: the Design Bachelor Program at the Bauru campus of the Paulista State University (n.d.), the Bachelor Program in Graphic Design at the Federal Fluminense Institute (n.d) and the Graphic Design College at the School of Communication and Digital Design (n.d.). Of these six programs, only the last one is private. The others are public programs.

The eight programs (including the Bachelor Program in Graphic Design at the Federal Fluminense Institute) represent only 0,02% of the 2641 existing programs in Brazil. According to INEP's (2021) Higher Education Census, these programs are regionally distributed as shown in Figure 1.

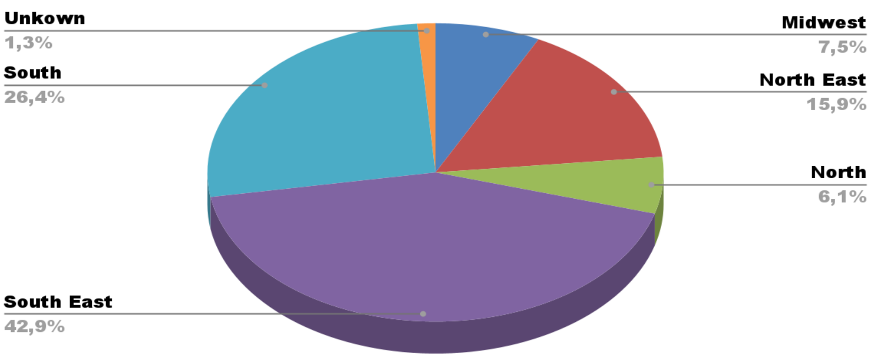

Figure 1. 2021s Graphic Design Programs at Brazilian Regions

2.2 The Bachelor Program in Graphic Design at the Federal Fluminense Institute (BPGD-FFI)

Uébe-Mansur et al. (2022) report that the Federal Fluminense Institute (FFI) is part of a vast government network for vocational education founded in 1909. Since its dawn, FFI has changed its name concerning its importance and increasing professional programs offered at different educational levels. The 1909s pedagogical focus was young apprentice education for poor people at the elementary education level. In 1942, the Brazilian government turned these elementary schools into high schools. And around 1959, these high schools became part of an education network named the Federal Vocational High Schools (FVHS). In 1978, the Brazilian government changed the FVHS educational network to the Federal Centres of Vocational Education (FCVE) and offered higher-level vocational courses.

In 2001, the Federal Centre of Vocational Education of Campos (FCVE-Campos), as part of the FCVE in Campos municipality of Rio de Janeiro state, created the Vocational Program of Graphic Design (VPDG). The VPDG aimed to train qualified professionals with autonomy skills for self-management of knowledge, abilities, and competencies to value their work in the market and society as capacity and resiliency for market-changing adaptations (IFF, 2015).

According to Cardoso (2013), society changed mainly from technological innovations profoundly affecting the Graphic Design market profession. And after two decades of its creation, providing professionals to the regional market, the Graphic Design program demanded adapting changes to the new world reality that is much more globalized, dynamic, technological, and multifaceted. Furthermore, educational models evolved, bringing pedagogical and legal advancements for new ways to think and make the education process happens.

An example of these new ways, in 2008 the FCVE turned into the Federal Network of Vocational Education (FNVE) by the Brazilian government, and in reason of that the FCVE-Campos changed its name to Federal Fluminense Institute (FFI) and began offering not only higher-level vocational courses but also bachelor courses. (Uébe-Mansur et al., 2022).

In 2017, the VPDG committee began to discuss changes in the program reflecting the transformations reported by Cardoso (2013) as the new academic possibilities related to the FCVE to FNVE change. For the challenge, the VPDG counted on an FFI department named Coordination of Methodologies and Technologies for Education (CMTE).

The CMTE department originated from a 2014s partnership between the Brazilian and Finland governments and was "(...) a pilot teacher development programme for vocational and higher education teachers (VET) designed to meet the strategic goals of the Ministry of Education in Brazil and the needs of Brazilian Federal Institutes." (Mahlamäki-Kultanen et al., 2015)

An official teamwork including the VPDG committee and CMTE members was formalised starting the challenge of creating not only a Bachelor Program in Graphic Design (BPDG) but also centred on a Project-based learning teaching approach.

The project implementation took three years since there were no similar programs in the Rio de Janeiro state. The closest program as a reference model was 1,398 kilometres far from Campos municipality in the Federal University of Santa Catarina, located in Florianópolis city, Santa Catarina state. School Anchor Project, sited in Cotia municipality, São Paulo state (far 739 kilometres from Campos municipality, was another academic reference for the project development since it is a high school based on Project-based learning where students are provoked to autonomous learning without knowledge fragmentation in subjects.

The most disruptive change from VPDG to BPDG is the syllabus program. VPDG organised its subjects according to a fragmented-knowledge structure, usually based on a cartesian approach. Furthermore, the VPDG syllabus program was not previewing students' experiences with new knowledge, for example, Digital Design. BPDG organised its syllabus on a project conception where the class (when offered) is only to scaffold the project's demands. Compared to VPDG, the BPDG syllabus promotes students' experience more in humanities, active and flexibility learning, and complex.

As shown in the figure 2, BPDG's syllabus has eight semesters/periods and three core categories: a) Basic Core N. 1 and Basic Core N. 2 (related to 1st to 2nd term), focused on theoretical background subjects; b) Project Cores N. 1 to N. 5 (from 3rd to 7th term); c) Complementary Core (from 1st to 7th term). In the 8th period, the students consolidate their knowledge in a Final Project, where an academic report is mandatory.

Only after concluding the two Basic Cores, the students can engage in the Project Core. The Project Core has five projects, with three teachers as advisors for each project.

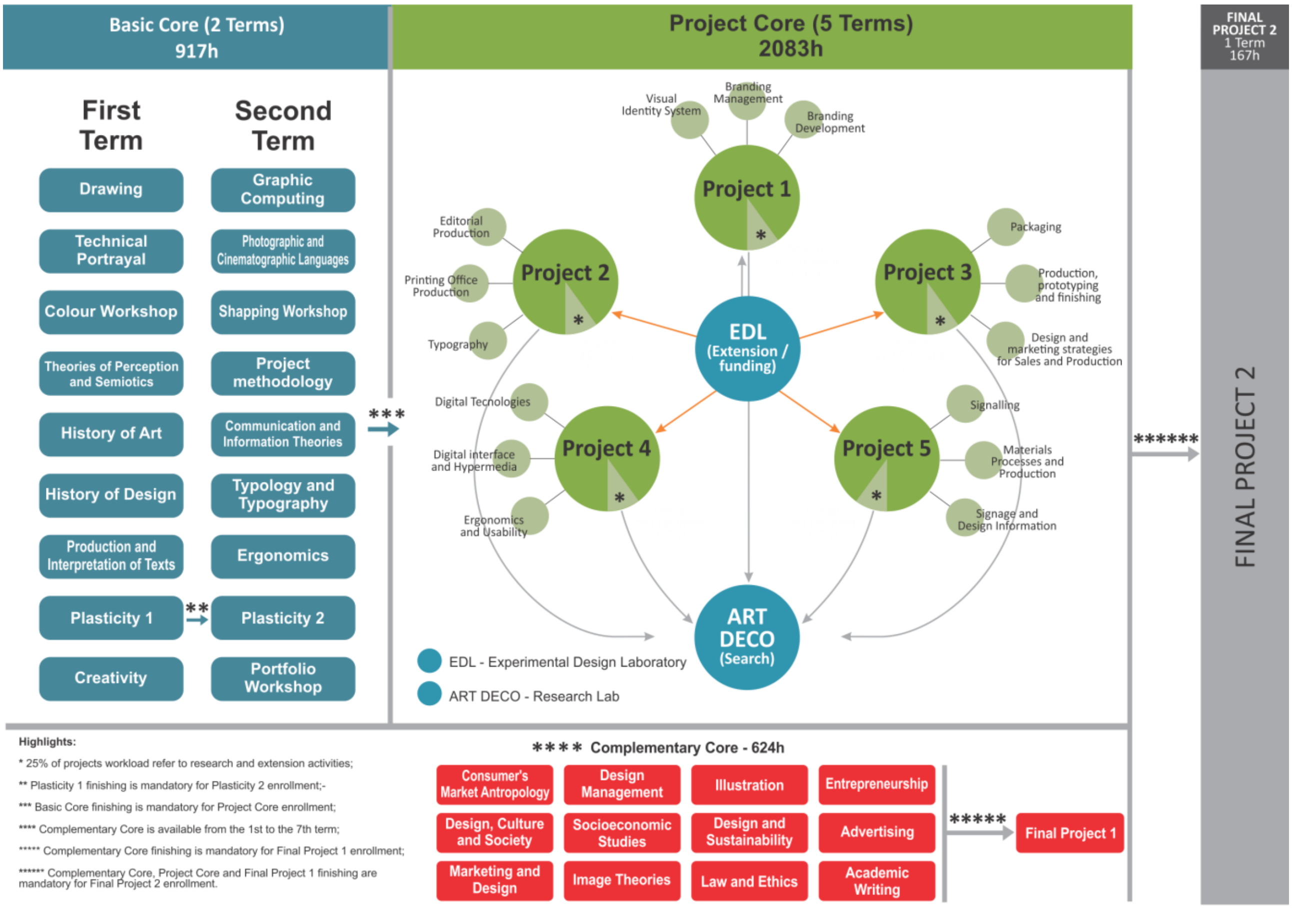

Figure 2 - BPDG's syllabus

3 Methodology

The study employed a qualitative approach focused on students from the 6th term that initiate their academic life since the 1st term in the new PBL-syllabus. A perception-based survey was conducted on 16 students using 5-Likert scale, ranging among: 1 (totally disagree), 2 (disagree), 3 (neutral), 4 (agree) and 5 (totally agree), and focus-group interviews with three teachers. The perception-based survey structure is according to the original Taneja's (2022) four categories related to the Methodology: Teamwork; Interpersonal Skills; Communication Skills; Goal-setting, and Project Management Skills. The fifth category is an innovation of this study from

Taneja's model and brings three open questions where the students could openly relate their positive and negative perceptions as also general perceptions and opinions.

After completing the questionnaire a focus group was conducted among students to take more perceptions related to the positive and negative students' opinions related to the General Aspects section.

4 Results Analysis

The results analysis structure is according to the methodology. The figures below gather the frequency of answers for each category's question. The students' comments on the General Aspects section permeate the four of Taneja's (2022) original categories.

4.1 Teamwork

In the Teamwork category (figure 3), only 62.5% of the students chose a scale of 4-5, referring to their ability to achieve better results in a group than they would have managed alone. The researchers tried to understand the gap, compared to the 84.8% from Taneja's studies. Some responses from students' that chose a 1-3 scale (37.5%): a) "The program needs to offer extra classes to increase team word experience"; b) "In general, the PBL works and needs few adjustments. A suggestion is trying to increase the number of meet days with three teachers. These are the most relevant class days". The answers indicate that few curricula adjustments are necessary. Another conclusion is that these students come from a traditional pedagogic approach experience and adaptations and depth changes are not fully experienced at the first moment. This conclusion is reinforced by the 81.25% of students who vote in "totally agree" (scale 5) when inquired if good teamwork is essential for the project's success. When inquired about responsibility shared among group members, 68.75% of students chose a 4-5. Despite this positive result (much better than 53,7% obtained in Taneja's study), 31.25% of the students chose a 1-3 scale. That result indicates how important PBL can yet be to these students that have not a collaborative sense of teamwork. The following inquiries are related to each team's encouragement to give inputs and collaborative learning from mutual members' constructive feedback. Both questions obtained 93.75% of votes related to a 4-5 scale

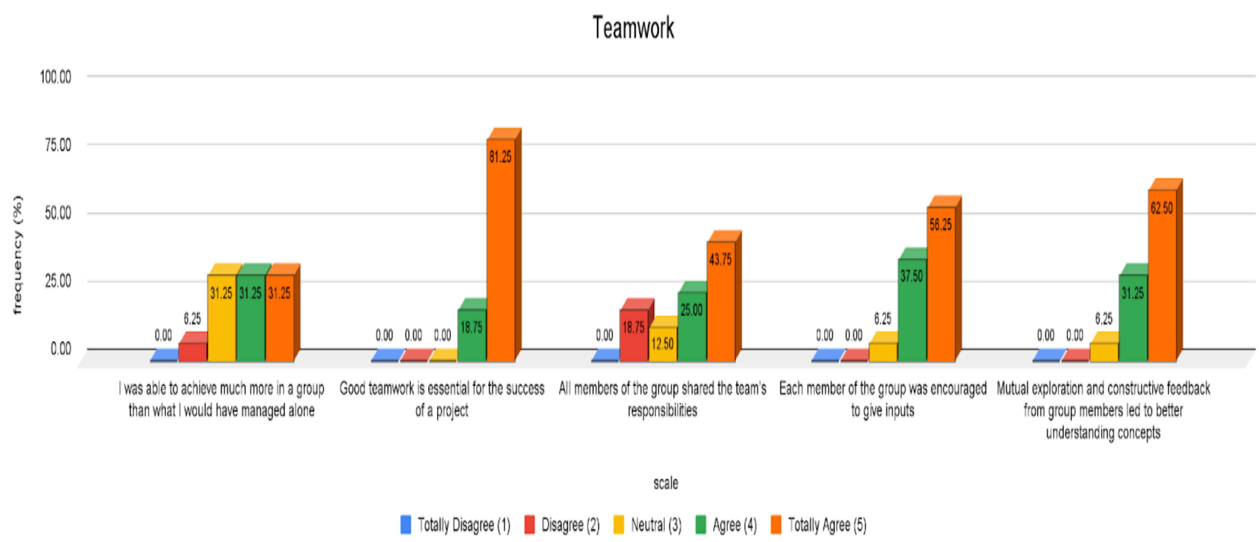

Figure 3 - Response frequency for Teamwork category's questions

4.2 Interpersonal Skills

According to figure 4, the first, second, and fourth questions of this category obtained 62.5%, 68.75%, and 71.25% of votes respectively in the 4-5 scales. The third question obtained 68.75% of votes on the 2-3 scale. Some students' answers from the fifth survey category (related to positive and negative aspects of PBL experience), like a) "It is not always easy to deal with a colleague who does not want to listen"; b) "The class split into groups or pairs brings a barrier to the PBL. I know this splitting makes a difference to PBL since it allows the students to deal with colleagues and achieve a project's complete view. But in my opinion, it works well only for the research and brainstorming steps. In the practising moment, some barriers can prejudice the plans' execution. For instance, the lack of confidence among group members randomly chosen by the teacher makes these students ashamed and uncomfortable expressing their opinions".

Frequently, the teachers prefer to split the students into groups randomly. A reason for this teacher's behaviour is that leaving the students free to choose their groups or pair will decrease the possibility of network improvement since they will prefer the same persons. A possible teaching strategy to increase students' rapport with fellow students and avoid this kind of result, can be for the teacher to promote socialisation dynamics to the students before the group splitting.

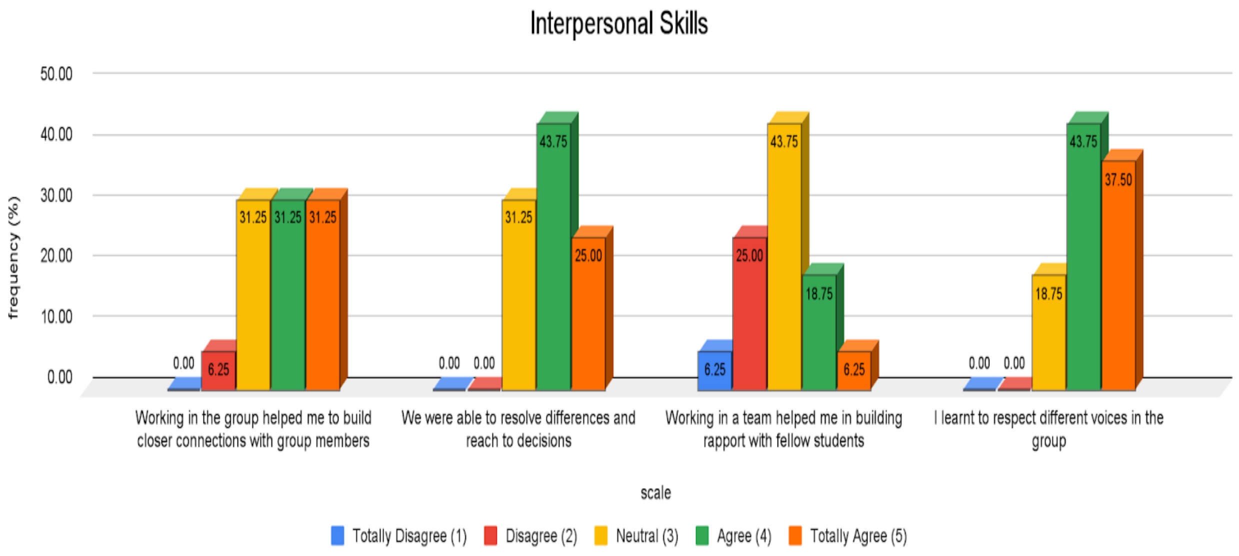

Figure 4 - Response frequency for Interpersonal Skills category's questions

4.3 Communication Skills

In a different way from the previous category centred on the final results of teamwork, the Interpersonal skills category (figure 5) is more centred on the person of the student her/himself. This category has four questions. The two first ones are focused on personal communication abilities: a) the ability to get the opportunity to articulate her/his ideas; b) the ability to drive conflict solutions. The two last ones on the group communication abilities: c) general group members to well listen to each other and d) general perception related to the group's good communication. 71.25% of students voted (at least) on the 4-5 scale for all questions related to this.

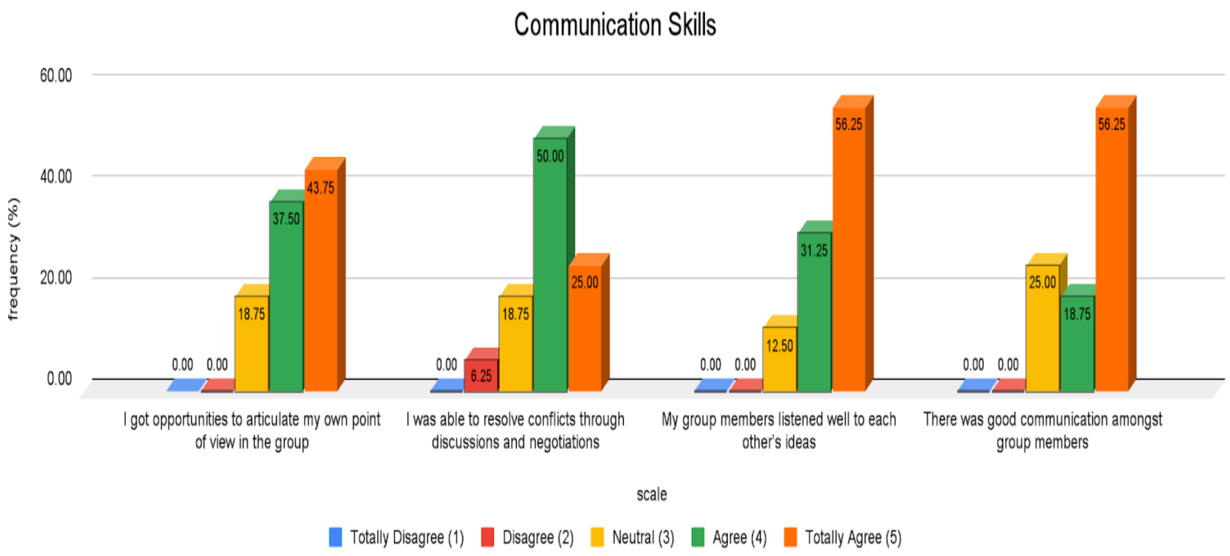

Figure 5 - Response frequency for Communication Skills category's questions

4.4 Goal-setting and Project Management Skills

This category (figure 6) has the most frequency of students choosing the 3 (neutral) scale in the question, obtaining at least 62.5% of students voting on the 4-5 scale. Trying to understand these results, the researchers resorted to open questions from category 5 (General Aspects): a) "Teamwork demands extra-efforts"; b) "Some demanded tasks haven't clear goals"; c) "It is not always easy to deal with a colleague who does not want to listen d) "A negative aspect is teammates not always are engaged in the same mood to solving the problems". Despite these negative perceptions, the students bring positive comments too: e) "I believe that in general, the team works the works have been fruitful"; f) "As a positive aspect, I believe that in this way (PBL) we have more contact with reality. Teachers could be more effective in interfering among students, regarding the participation of the students in the group".

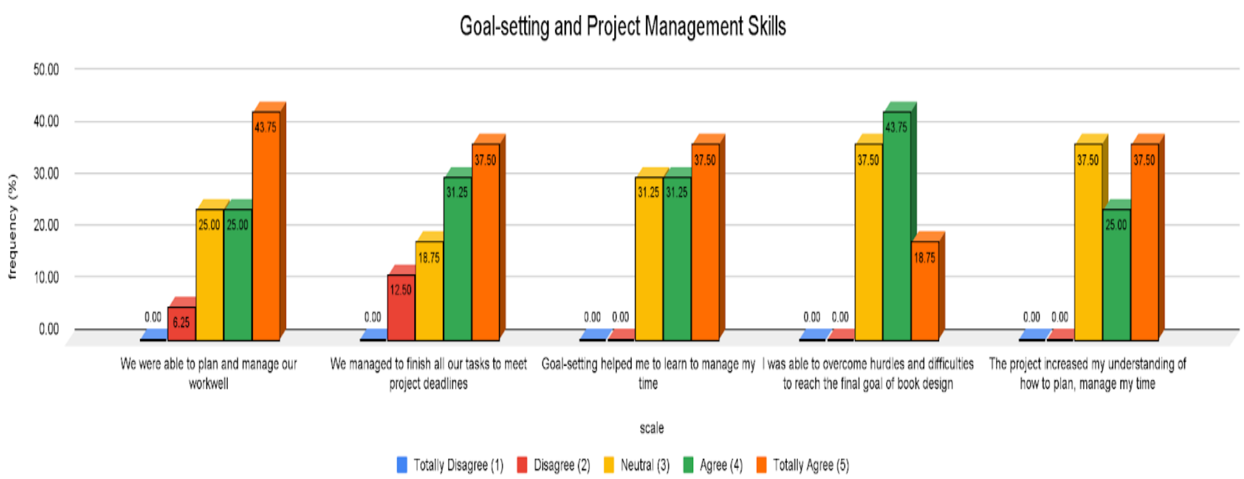

Figure 6 - Response frequency for Goal-setting and Project Management Skills category's questions

5 Conclusion

Despite the results of 62.5% obtained in the first teamwork category question (section 5.1), compared to the other questions' results, it is evident that the students have a sense of teamwork and its advantages for project development.

Results related to Interpersonal Skills indicate that teachers can improve their pedagogical practices. Possibilities for improvements are active and cooperative learning methods like Jigsaw Classroom and Fishbowl strategy (Social Psychology Network, n.d.; Southern Poverty Law Center, n.d.).

Outcomes from Communication Skills are close to Taneja's studies results, which means the students noticed a significant improvement in Communication skills from the PBL experience.

Related to the response frequency for Goal-setting and Project Management Skills category's questions, according to the students' reports, the researchers concluded that the results evidence a natural process of maturing since they are between 18-25 years old. Despite this initial conclusion, some adjustments will happen related to teacher interference intending to decrease the students' lost perceptions. An example of a possible adjustment is increasing the students' participation as tutors. This solution could improve students' confidence related to Interpersonal Skills, as referred to by Leão et al. (2022, p. 219), "(...) students see the tutor-student more near them as a partner, and the tutor-teacher as the more-experienced partner".

According to the research questions, this study identified that changes in a vocational graphic design program traditional-curriculum-centred to a Bachelor of Graphic Design PBL-curriculum-centred are possible. Sessions 2.2 and 3 describe the program syllabus implementation as the research methodology, answering the research questions related to how the shifting process from traditional to PBL could happen and what results could be possible.

PBL-curriculum Bachelor Graphic Design is possible since carefully implemented. The profound changes in the class status quo (mainly in student and teacher relationships) demand special care related to process actors' expectations and frustrations.

PBL teaching demands a teacher's behaviour as a mediator since the teaching's final purpose is to promote student autonomy and confidence. For this reason, it is not easy to converge the natural teacher's sense of loss and discomfort, as also student maturity for more autonomous and confident learning. Moreover, students' assessments are more individual, demanding a more thorough look from the teacher and improvement developments related to assessment methods.

Despite these initial difficulties, students' and teachers' feedback is positive, as also the growing maturity among these process actors.

6 References

Aldabbus, S. (2018). Project-based Learning: Implementation & Challenges. International Journal of Education, Learning and Development 6(3), 71-79.

Bachelor Program in Graphic Design (n.d.) Retrieved April 10, 2023, from https://www.facebook.com/cursodesigniff/about?locale=pt_BR

Cardoso, R. (2013). Design para um Mundo Complexo (Design for a Complex World). São Paulo, Brazil: Cosac Naify.

Dahlgren, M., Castensson, R., and Dahlgren, L. (1998). PBL from the teachers' perspective. Higher Education. 36(4), 437-447.

Federal University of Ceará (n.d.). Bachelor Program. Retrieved April 7, 2023, from https://design.ufc.br/pt/o-curso/

Federal University of Pernambuco (n.d.). Design Bachelor Program. Retrieved April 7, 2023, from https://www.ufpe.br/design-bacharelado-cac

IFF (2015). Projeto Pedagógico Curso de Tecnologia em Design Gráfico (Pedagogic-projetc of Vocational Program in Graphic Design). Campos dos Goytacazes, Brazil: IFF.

INEP (2021). Censo da Educação Superior 2021 (Higher Education Census 2021). Retrieved April 10, 2023, from https://www.gov.br/inep/pt-br/acesso-a-informacao/dados-abertos/microdados/censo-da-educacao-superior
Jones, B. (2019). Good practice: Scaffolded, collaborative project-based learning. Journal of the European Honors Council, 3(1), 1-16. https://doi.org/10.31378/jehc.85
Leão, C., M. Abreu, F., Alves, A., Fernandes, S. (2022) PBL tutoring dynamics in first-year of Industrial Engineering and Management Program. . PAEE2022-International Symposium on Project Approaches in Engineering Education. 1, 212-220.
Mahlamäki-Kultanen, S., Joyce, B., Ryymin, E., Viskari, M., Heikkilä, L. (2015) Brazilian VET teachers´ strategies to transfer their learning in a Finnish-Brazilian teacher education programme. Turku, Finland: AMK-lehti/UAS Journal. Retrieved April 10, 2023, from https://uasjournal.fi/tutkimus-innovaatiot/brazilian-vet-teachers-strategies-to-transfer-their-learning-in-a-finnish-brazilian-teacher-education-programme/
Paulista State University (n.d.). Department of Design. Retrieved April 7, 2023, from https://www.faac.unesp.br/#!/departamentos/design/
PBS NewsHour. (2013). School District Uses Project-Based Learning Over Testing. Season PBS. (n.d.). PBS.org. https://www.pbs.org/video/school-district-uses-project-based-learning-over-testing-1372280773/
Sandra, F., Alves, A.C., Uébe-Mansur, A.F. (2021) Student-Centered Assessment Practices: An Integrated Approach With Project-Based Learning (PBL). In A. S. Moura, P. Reis, M. N. D. S. Cordeiro (Ed.) Handbook of Research on Determining the Reliability of Online Assessment and Distance Learning. (pp. 213-243). Hershey PA, USA: IGI Global. https://doi.org/10.4018/978-1-7998-4769-4
School of Communication and Digital Design (n.d.) Graphic Design College. Retrieved April 7, 2023, from https://ecdd.infnet.edu.br/rj/faculdade/design-grafico/
Social Psychology Network. (n.d.). The Jigsaw Classroom: Overview. Retrieved April 7, 2023, from https://www.jigsaw.org/
Southern Poverty Law Center (n.d.). Fishbowl. Retrieved April 7, 2023, from https://www.learningforjustice.org/classroom-resources/teaching-strategies/community-inquiry/fishbowl
Stoicoiu, C. and Cain, K. (2014). Industrial Projects in a Project-Based Learning Environment. In Proc. 2014 Canadian Engineering Education Association (CEEA14) (pp. 1–6).
Taneja, K. (2022). Employing project-based learning to foster essential professional skills in students of graphic design. In IDA: International Design and Art Journal. 4(2), 173-184. https://www.idajournal.com/index.php/ida/article/view/171
Uébe-Mansur, A. F., Rôças, G., Braga, E.S.O., Jesus, N.F.S., Miguez, L.M. (2022) COVID-19 Pandemic Effects on Brazilian Postgraduate Research: An Exploratory Study at Two Federal Institute Programmes. In A. Alves and N. Hattum-Janssen (Ed.) Training Engineering Students for Modern Technological Advancement. (pp. 290-312). Hershey PA, USA: IGI Global.

Project-Based Learning in Industrial Engineering and Management: analysis of three curricular projects

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Abstract

In the 2nd semester of 2004/05 the Department of Production and Systems (DPS) of the Engineering School, University of Minho (UM), Portugal, deployed the first Project-Based Learning (PBL) approach, involving the freshman students of the Industrial Engineering and Management Integrated master's degree (MIEGI). Since then, in every year, without exception, new PBL editions have been held in different years of the programme, each with its own characteristics. The experience gained over time has allowed the change/refinement of conceptual and operational aspects of the projects, always bearing in mind a perspective of continuous improvement. In 2021/22 MIEGI underwent a major restructuring and gave rise to two programs: a 3-year bachelor's degree (LEGI) and a 2-year master's degree (MEGI). The curricular structures of these two programs include four integrated projects: three from LEGI (PIEGI1, 1st year; PIEGI2, 2nd year; and PIEGI3, 3rd year) and one from MEGI (PIEGI, 1st year). This paper aims to describe and compare three of these projects, more specifically PIEGI1, PIEGI3 and PIEGI, from a conceptual and operational point of view. One of the most important aspects in this description and comparison is the main objective of each project, which is defined considering the transversal and technical competences that make sense to develop in the respective curricular year. From the point of view of the development of technical competences, these derive mostly from the project supporting courses involved. Furthermore, several other aspects are considered, namely: problem characteristics, number and size of student teams, number and type of tutors, involvement of companies, milestones, deliverables, assessment model, coordination team composition, premises, etc. The findings show that these projects result from an integrated and complementary approach whose overall goal is to develop in students, throughout each year of the programme, key competences for their professional life.

Keywords: Engineering Education; Active Learning; Project-Based Learning; Curricular Projects.

1 Introduction

Projects are part of the identity of the engineering curriculum. Probably all engineering programs worldwide have at least a project course in one semester. Nevertheless, many changes have occurred in the last 50 years in engineering education (Kolmos & De Graaff, 2014). Research in engineering education has contributed with evidence about Project-Based Learning (PBL), helping instructors to understand its effectiveness in terms of students' learning (Guo et al., 2020). Thus, it is not surprising that PBL becomes a popular approach in engineering (Kolmos & De Graaff, 2014), particularly because it can be implemented in different ways, according to the educational context (Helle et al., 2006):

- Project exercise: students should apply knowledge in the context of a subject area. This is the most traditional PBL approach.
- Project component: the scope is larger, and the project becomes more interdisciplinary. It is connected to the real-world issues and students' learning focuses on working in teams to find out a solution for the problem. Often, project is supported by the courses studied in parallel.
- Project orientation: The curriculum is project oriented, thus PBL is the whole curriculum philosophy of the engineering program.

Considering the diversity of PBL models and practices, as well as its dissemination, the PBL concept cannot be reduced to a curriculum level or to a teaching methodology to be implemented. PBL definition must be a defined set of learning principles, namely: (i) the outcomes related to the learning objectives, (ii) type of problems and projects, (iii) progression, size, and duration, (iv) students' learning (by working in teams); (v) academic staff and facilitation, (vi) space and organization, (vii) assessment and evaluation (Kolmos & Graaff, 2015).

These principles can be identified in different PBL models and practices worldwide. Referring some examples, also cited in the MIT report 'The Global state of the art in engineering education' by Graham (2018); in United States, Olin College; in Latin America, Monterrey Tech in Mexico; in Australia, Charles Sturt University; in Asia, Singapore University of Technology and Design; in Europe, Aalborg University; University College of London.

In Portugal, the Department of Production and Systems (DPS) of the School of Engineering of the University of Minho (UM), has almost two decades of experience in the implementation of Project-Based Learning (PBL) in its main Industrial Engineering and Management (EGI) programs, with a core team of teachers and researchers that has undergone little changes over time. A large dissemination of the work developed was carried out, encompassing many different aspects such as: PBL management (A. Alves et al., 2016; Lima, Dinis-Carvalho, Sousa, Alves, et al., 2017) and operationalization (A. Alves et al., 2017; Lima et al., 2012), teachers workload (A. C. Alves et al., 2016; A. C. Alves, Moreira, Leão, et al., 2019), tutors role (A. C. Alves et al., 2017; Leão et al., 2022), assessment models (Fernandes et al., 2012a, 2012b, 2021; Moreira et al., 2009), students' feedback (A. C. Alves et al., 2020) production systems prototypes (Moreira & Sousa, 2008; Sousa, Moreira, et al., 2014), serious games (Sousa, Alves, et al., 2014) interaction with industry (Lima et al., 2018), connection between PBL and industry demand for competences (Lima, Dinis-Carvalho, Sousa, Arezes, et al., 2017; Lima et al., 2014; Mesquita et al., 2009).

The main objective of this paper is to describe and analyse the PBL approach adopted by DPS in its two main Industrial Engineering and Management programs (Bachelor's degree – LEGI, and, Master's degree - MEGI), by comparing three of the four integrated projects included in the curricular structure of these programs: (i) Integrated Project in Industrial Engineering and Management I (PIEGI1-LEGI), Bachelor's degree, 1st year, 1st semester; (ii) Integrated Project in Industrial Engineering and Management III (PIEGI3-LEGI) Bachelor's degree, 3rd year, 2nd semester; and Integrated Project in Industrial Engineering and Management (PIEGI-MEGI), Master's degree, 1st year, 1st semester. The comparison addresses both conceptual and operational aspects.

The paper is structured in five sections. After the current introduction, section 2 describes the methods inherent to this work. The third section is dedicated to the description and characterization of the three integrated projects. Section 4 presents and discusses the results, and, lastly, section 5 provides the concluding remarks.

2 Methods

For the development of this study, a document analysis was carried out based on the project guide (document containing the most relevant information about each project) and, although with less detail, the institutional assessment reports of the course unit (CU). In relation to these last reports, only the overall satisfaction level of the students was analysed in relation to the three PBL integrated projects under study.

The analysis of each project (sections 3.1, 3.2 and 3.3) was led by its project coordinator with the support of the remaining authors, also making use of feedback from other teaching staff, collected informally throughout the semester.

To characterize each integrated project, the following set of parameters was defined: (i) number of ECTS (European Credit Transfer and Accumulation System), (ii) duration, (iii) curricular year, (iv) number of project supporting courses, (v) number of project supporting courses of the industrial Engineering and management area, (vi) number of companies involved, (vii) numbers of students involved, (viii) number of teams (and teams' size), (ix) size of the coordination team, (x) number of tutors, (xi) role of the tutors, (xii) premises, (xiii) number of milestones, (xiv) number of deliverables, (xv) number of seminars, (xvi) assessment model, (xvii) peer assessment, and (xviii) students satisfaction level.

The comparison of the PBL projects was based on this set of characterisation parameters, and it should be noted that the information regarding the last parameter was gathered from the institutional CU report.

3 Analysis of the Projects

This section contains the characterization of the three integrated projects under study, according to the parameters defined in the previous section, but also adding other information, namely in terms of technical and transversal competences development.

3.1 PIEGI1 – LEGI

The Industrial Engineering and Management bachelor's degree (LEGI) has six CU in the 1st semester of the 1st year, each holding five ECTS (1 ECTS means 28 hours of student work). Five CU contribute as project supporting courses (PSC) for the Integrated Project PIEGI1 (Table 1). Two are taught by the UM Sciences School: Calculus for Engineering, and Linear Algebra for Engineering and the remaining four are from the UM Engineering School: Computer Programming I, Integrated Project on Industrial Engineering and Management 1 (PIEGI1), Introduction to Economics Engineering and Introduction to Industrial Engineering and Management. As with any engineering program, LEGI's 1st year includes Science, Technology, Engineering and Mathematics (STEM) courses that must be integrated in into an interdisciplinary project to solve a challenge provided to teams (A. C. Alves, Moreira, Carvalho, et al., 2019).

Table 1. Project Supporting Courses for PIEGI1 – LEGI (bachelor's degree, 1st year).

Course Unit	Scientific Area	ECTS (credits)
Calculus for Engineering	Mathematics	5
Linear Algebra for Engineering	Mathematics	5
Computer Programming I	Engineering Sciences	5
Introduction to Economics Engineering	Industrial and Systems Engineering	5
Introduction to Industrial Engineering and Management	Industrial and Systems Engineering	5

The challenge given to the students in the context of the PIEGI1 is focused, since the first edition, on sustainability issues (A. C. Alves et al., 2018; Colombo et al., 2015; Moreira et al., 2011). The 2022/23 PIEGI1 edition was no exception and addressed the "Separation, remanufacturing, revaluation, upcycling and/or recycling of end-of-life clothes" theme. Teams should design a product and the corresponding production system for the treatment of end-of-life clothes, reducing those that will be sent to landfills.

The PIEGI1 project involved teachers from different courses, voluntary tutors (department lecturers and third year LEGI students) and, sometimes, voluntary educational researchers in a total of 17 team members to manage in the edition of 2022/23. The project is regularly developed in the 1st semester, i.e. from September to January. The coordination team defines the project management (time, resources, theme and so on), before classes start (1st week of September). More details are provided in A. C. Alves et al. (2021). In the first week of classes, the project is presented to freshman students, which arrive at university one week before, in a session organized by the coordination team. In this session, the learning project guide is delivered to the teams, who are also formed in this session. This guide is a word document prepared by the coordination team for students to read and follow, explaining all details of PBL process organization, coordination team contacts, learning outcomes expected from each course, time schedules, tutors' role, among other important elements. In this edition, 68 freshman students were organized in eight teams of 7 to 9 members. Assessment included six milestones with deliverables during the semester. The team assessment counts for 90% and the remaining 10% comes from a challenge in student pairs, named IEM@ProjectNetworking (A. Alves et al., 2013; A. C. Alves et al., 2022).

3.2 PIEGI3 – LEGI

The CU of PIEGI3-LEGI, in 2021/22 , also follows a PBL approach, with an integrated project developed by seven teams of students (total of 61 students, teams with 8 to 9 members) in interaction with four companies (one from the metal-mechanics area, one from the furniture area and two from the textile area), and involving as Project Supporting Courses (PSC) all the five CU of the semester (Table 2). Three of the companies have two teams assigned and a fourth company has only one team.

Table 2. Project Supporting Courses for PIEGI3 – LEGI (bachelor's degree, 3rd year).

Course Unit	Scientific Area	ECTS (credits)
Data Analytics	Engineering Sciences	5
Decision Models	Industrial and Systems Engineering	5
Logistics and Supply Chain Management	Industrial and Systems Engineering	5
Manufacturing Planning and Control	Industrial and Systems Engineering	5
Project Analysis in Industrial and Engineering Management	Industrial and Systems Engineering	5

With PIEGI3-LEGI students must be able to develop a team project, using data provided by companies, consisting of two parts: (i) description and characterization of the company (including the production system), and, (ii) application of tools/techniques/methodologies (e.g. for production system diagnostics) using company data.

In terms of technical competences, with the CU of Data Analytics, teams will use data organization and pre-processing techniques on provided datasets, interacting with the other CU supporting the project. Based on the CU Logistics and Supply Chain Management, teams will characterize the supply chain and describe a chosen storage unit, in close articulation with the CU Manufacturing Planning and Control. In the context of this last CU, students should carry out some key production planning and control functions using data provided by the company. In terms of Decision Models, teams are expected to contribute to a medium-long term strategic analysis regarding the challenges facing the company, given current trends, namely digital and green. In addition to the technical competences inherent to each CU, it is intended that transversal competences are also developed (e.g. communication, teamwork, leadership).

The coordination team is composed by the 10 teachers, of which 4 are tutors, associated to the CU of the semester. The tutor supports the student teams in what concerns the project management, without, however, interfering in the technical contents. The teams have three specific project rooms during the project supporting weekly sessions and during the periods when they do not have classes.

Regarding the project planning, the coordination team started to meet about three months before the beginning of the semester, to define a whole set of conceptual and operational aspects, highlighting the definition of objectives and the contact/selection of companies, as well as the scheduling of the entire process (milestones, assessment moments, etc.). Ten milestones are defined, namely 9 seminars (4 from companies and one from each CU) and 2 presentation/discussion sessions (intermediate and final). Three deliverables are stipulated (intermediate presentation, final presentation, and final report).

Student assessment is based on: (i) intermediate presentation (deliverable and discussion) – 10%, (ii) final presentation (deliverable and discussion) – 15%, (iii) final report – 65%, and (iv) seminars' participation – 10%. Finally, each team can choose to conduct peer assessment sessions if they want to distinguish colleagues with different performances within the team.

3.3 PIEGI – MEGI

The 1st semester of the 1st year of the Industrial Engineering and Management Master program (MEGI) is a program designed as a continuation of the LEGI bachelor previously referred. During this semester, the students have 6 courses of 5 ECTS each. The first 4 courses of Table 3 support the Integrated Project in Industrial Engineering and Management (PIEGI) during a whole semester project developed in interaction with industrial companies. The sixth course of the list may use the project as a case for simulation.

In the academic year of 2022/2023, from mid-September 2022 to mid-January 2023, 54 students organized themselves in 7 teams of 7 to 8 students each, and one teacher was assigned as supervisor. Each team made almost weekly visits to a company (one for each team), analysing a part of the production system from the perspective of the project supporting courses. At the end of the semester, they present and defend a proposal of improvement and whenever possible implement and evaluate part of the proposal. As an example, students modelled and analysed a production cell and proposed an improvement of its performance. They must do this considering the best workplace conditions for the cell workers. Overall, it is expected, and supported by one of the courses, that each team applies agile project management approaches during the semester.

Table 3. Courses for the 1st semester of the 1st year of MEGI master's degree.

Course Unit	Scientific Area	ECTS (credits)
Process Modelling and Analysis	Industrial and Systems Engineering	5
Production Systems Advanced Organization	Industrial and Systems Engineering	5
Industrial Project Management	Industrial and Systems Engineering	5
Human Factors and Ergonomics	Industrial and Systems Engineering	5
Integrated Project in Industrial Engineering and Management	Industrial and Systems Engineering	5
Modelling and Simulation	Industrial and Systems Engineering	5

The project has three main phases and milestones (Figure 1), during which the students should tackle real industrial problems of a company and develop solutions to mitigate those problems. These are general guiding phases and milestones, as students may be in slightly different stages at the end of the milestones. Nevertheless, these phases will help all stakeholders to understand what is expected at a specific time. Students will have weekly classes of project, organized as team meetings, during which they will be supported by their supervisors. Additionally, project support courses instructors will refer and use the project as an object of learning during their classes whenever appropriate.

Figure 1. PIEGI-MEGI project phases.

The formative assessment process is based on the supervisor's weekly support and milestones feedback delivered by all project supporting courses. The summative assessment process is mainly based on the assessment of the deliverables at each milestone: Phase 1 – project plan (5%); Phase 2 – diagnosis presentation (20%); Phase 3 – proposals presentation (35%) and article (40%). If the article is published and presented, the team may apply for a bonus of 5% in the next formal evaluation phase. Additionally, there is the possibility for each team to make a peer assessment to distinguish individual performance.

One particularity of the assessment model in this project is the influence that it has in the project supporting courses grades, as each instructor agrees to use a component of 20% of their grade based on the team project grade. This mechanism creates a real interconnection between the project course and the project supporting courses, which is also supported by the integration of these teachers in the assessment process of the project.

4 Discussion

To support the comparison between the three PBL integrated projects, Table 4 summarizes the information gathered in the analysis of each of them (section 3). This information refers to the last edition of these projects, which for PIEGI1-LEGI and PIEGI-MEGI occurred in the 1st semester of 2022/23 and for PIEGI3-LEGI in the 2nd semester of 2021/22 (the 2022/23 edition is still ongoing). Although the three integrated projects presented here share some common aspects, they also have some significant differences. This discussion will focus mainly on the aspects that clearly distinguish them. A first noteworthy aspect is that the weight of CU in the scientific area of industrial and systems engineering increases as students progress through their study plan. This is quite common in most engineering programmes, and it influences what is expected from students in their projects. Unlike in the second and third projects (PIEGI3 - LEGI and PIEGI3 - MEGI), in the 1st year project (PIEGI1 - LEGI) there are no companies involved and, therefore, no actual real context in which the students carry out their projects.

The whole project is carried out within the university. However, in the other projects, the students already have access to a real industrial context to develop some skills in applying concepts and tools, and other professional skills, as well as to identify the relevance and adequacy of the topics covered in the various CU.

Another noteworthy feature that distinguishes one of the projects is the role of the tutor. In the most advanced project (PIEGI-MEGI), the role of the tutor is no longer so focused on supporting the management of the project and the team but is more of a technical supervision role involving technical support. This difference stems from the greater demands of this type of project in terms of developing and implementing technical solutions in companies.

Table 4. Comparison of the three PBL integrated projects in industrial engineering and management at UM-DPS.

	PIEGI1 – LEGI	PIEGI3 - LEGI	PIEGI - MEGI
General objective	Design of a production system and of a production process to produce a sustainable product	Company characterization and application of tools / techniques / methodologies (e.g. for production system diagnostics)	Analysis, diagnosis, and proposals for improvement of part of a production system from an industrial company, based on concepts and tools related to Lean, process modelling, ergonomic workstation, using agile project management approaches
# ECTS	5	5	5
# Duration	1 semester	1 semester	1 semester
Curricular year	1st	3rd	1st
# Project supp. courses	5	5	4
# Project supp. courses of industrial eng. and manag. area	40%	80%	100%
# Companies involved	-	4	7
# Students	68	61	54
# Teams (teams' size)	8 (7-9 elements)	7 (8 -9 elements)	7 (7-8 elements)
# Coordination team	17	10	7
# Tutors	8	4	6 (supervisors)
Tutors' role	Team monitoring and non-technical support	Team monitoring and non-technical support	Team monitoring and technical support
Premises	Specific project rooms (shared)	Specific project rooms (shared)	-
# Milestones	6	11	3
# Deliverables	6	3	4
# Seminars	-	8	-
Assessment model	55% Reports 20% Presentations 25% Prototypes and blog	10% Intermediate presentation 15% Final presentation 65% Final report 10% Seminars	5% Initial plan 20% Diagnosis presentation 35% Final presentation 40% Article
Peer assessment	Compulsory (3 sessions)	Optional	Optional
-	-	-	-
Students' satisfaction*	86%	74%	76%

* Information gathered from the institutional CU reports.

Students' satisfaction is an issue that clearly deserves some attention. As can be observed in Table 4, the project that generated the highest satisfaction was the first project while the second obtained the least positive result. These results contradict teachers' initial perceptions as they expected that real-life projects would result in greater student satisfaction. The possible reasons that can explain this difference might be related, according to teachers' intuition, to the fact that, in the first project, students have just entered university and this project allows them to experience a challenge as a team that they had probably never experienced before. In addition, this team project, due to its characteristics, creates favourable conditions for students getting to know each other and deepening bonds of friendship and companionship.

The main reason that can be pointed out for the low satisfaction shown by the students regarding the second project is that it was its first edition (following the major restructuring of the MIEGI programme) and therefore there were aspects that did not work as well, namely in terms of company interaction.

Regarding the last project (PIEGI - MEGI) the student satisfaction with the project was below teachers' expectations. This project takes place in companies where students' teams must perform analysis and diagnosis as well as proposing and implementing improvements. The project is quite challenging and for many students is the first experience as a near professional of industrial engineering. An important question to ask is why does such a project not provide at least the same level of satisfaction as the 1st year project (PIEGI1-LEGI)? Perhaps the fact that the 1st year project was an extraordinary personal experience for being the first experience of its kind is one of the reasons. Also, probably because the students, after other project experiences, became more demanding in terms of expectations. Another possible reason is related to the difficulties that students typically experience in dealing with real-life contextual challenges for which they are not prepared. Examples of these challenges are difficulties in setting up appropriate meetings, in dealing with different organisational behaviours and cultures, in communicating effectively, in clearly identifying the data they need and in dealing with incomplete (or even contradictory) data, among others. To better support and ground the results of this study, future work will focus on a qualitative study to collect evidence from students about the strengths and weaknesses of each of the three PBL approaches compared in this study, driving conclusions for the improvement of the conceptual and operational aspects of PBL approaches carried out in these two engineering programs.

In general, this study provides findings about a specific engineering program which has developed and improved its own model over time, creating its own identity, which does not necessarily mean implementing the exact same approach across the program. In other words, the three projects followed the same PBL principles but, in practice, they were quite different, based on the objectives and characteristics of each of the contexts (e.g., number of students, resources available, etc.).

5 Conclusion

The 1st year project (PIEGI1-LEGI), in addition to the development of the technical project itself, aims to provide students with a PBL approach that they have probably never experienced. Thus, besides the technical competences it develops in students, PIEGI1-LEGI plays a crucial role in the development of transversal competences (teamwork, communication, time management, conflict management, etc.), which will be crucial throughout the entire academic and professional path, of these students.

The 3rd year project (PIEGI3-LEGI) puts student teams in direct contact with the industrial reality, not in the sense of being mere visitors (these can already take place in previous years), but rather, and for the first time, with the objective of characterizing productive systems and applying tools / techniques / methodologies that they learn at the university, using real data, and that allow a diagnosis of these productive systems to be made. Thus, in comparison with PIEGI1-LEGI, the most distinctive feature of PIEGI3-LEGI is the fact that the work of the teams is carried out in direct interaction with companies, thus forcing students to face all the difficulties inherent to this type of work (identification and collection of information, interaction/communication with industry professionals, etc.).

MEGI's 1st year project (PIEGI-MEGI) is the one that goes further in terms of requirements, but which, for that very reason, also allows to students to go deeper in terms of competences development. In PIEGI-MEGI each team of students has its own company (in PIEGI3-LEGI each company received two teams) and the project starts with the diagnosis of the productive system, or part of it (like PIEGI3-LEGI, but more detailed), followed by the formal development of improvement proposals (not expected in PIEGI3-LEGI) and eventual implementation.

Thus, it can be seen that the three projects targeted by this study were designed and implemented in order to have complementary objectives. This approach resulted from the experience that the core team of teachers and researchers has acquired over nearly two decades of working with PBL. It is the authors' conviction that these projects represent an excellent preparation for the students' final challenge, which occurs in the 2nd year of MEGI, and that is the realization of the individual master thesis project. Perhaps this is why the overwhelming majority of MEGI students (often 100%) choose to carry out their dissertation in a company, when there is also the possibility of carrying out an academic dissertation.

Finally, to conclude, the PBL model presented in this paper has been considered sustainable over the time mainly due to the following three main factors: (i) level of collaboration, motivation and commitment of the faculty team engaged in the projects; (ii) ongoing research on PBL carried out by the faculty team, that helped reflecting about the practice and improving the model; (iii) institutional support in terms of considering PBL as an added-value for students' learning.

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6 References

Alves, A. C., Fernandes, S., Fernandes, S., Moreira, F., Lima, R. M., Carvalho, J. D., Sousa, R. M., Mesquita, D. , & Hattum-Janssen, N. van. (2021). Project-Based Learning: implementação no primeiro ano de um curso de Engenharia. In *Project-Based Learning: implementação no primeiro ano de um curso de Engenharia*. https://doi.org/10.21814/uminho.ed.26

Alves, A. C., Moreira, F., Carvalho, M. A., Oliveira, S., Malheiro, M. T., Brito, I., Leão, C. P., & Teixeira, S. (2019). Integrating Science, Technology, Engineering and Mathematics contents through PBL in an Industrial Engineering and Management first year program. *Production*, *29*. https://doi.org/10.1590/0103-6513.20180111

Alves, A. C., Moreira, F., Leão, C. P., & Carvalho, M. A. (2018). Sustainability and circular economy through PBL: Engineering students' perceptions. *WASTES - Solutions, Treatments and Opportunities II - Selected Papers from the 4th Edition of the International Conference Wastes: Solutions, Treatments and Opportunities, 2017*. https://doi.org/10.1201/9781315206172-64

Alves, A. C., Moreira, F., Leao, C. P., & Fernandes, S. (2020). Ten years of positive feedback on Project-Based Learning from first year engineering students perspective. *ASME International Mechanical Engineering Congress and Exposition, Proceedings (IMECE)*, *9*. https://doi.org/10.1115/IMECE2020-23212

Alves, A. C., Moreira, F., Leão, C. P., Pereira, A. C., Pereira-Lima, S. M. M. A., Malheiro, M. T., Lopes, S. O., & Oliveira, S. (2019). Industrial engineering and management PBL implementation: An effortless experience? *International Symposium on Project Approaches in Engineering Education*, *9*.

Alves, A. C., Moreira, F., Leao, C. P., & Teixeira, S. (2017). Tutoring experiences in PBL of industrial engineering and management program: Teachers vs students. *ASME International Mechanical Engineering Congress and Exposition, Proceedings (IMECE)*, *5*. https://doi.org/10.1115/IMECE2017-71306

Alves, A. C., Oliveira, S., Leão, C. P., & Fernandes, S. F. (2022). IEM@ProjectNetworking revisited: freshmen students closer to professional practice. *PAEE/ALE'2022, International Conference on Active Learning in Engineering Education*. https://doi.org/10.5281/zenodo.7057834

Alves, A. C., Sousa, R. M., Fernandes, S., Cardoso, E., Carvalho, M. A., Figueiredo, J., & Pereira, R. M. S. (2016). Teacher's experiences in PBL: implications for practice. *European Journal of Engineering Education*, *41*(2). https://doi.org/10.1080/03043797.2015.1023782

Alves, A., Carvalho, J. D., Mesquita, D., Fernandes, S., & Lima, R. M. (2013). IEM@ProjectNetworking: bringing first year students closer to professional practice. *International Symposium on Project Approaches in Engineering Education (PAEE2013)*, 1–7.

Alves, A., Moreira, F., Fernandes, S., Leão, C. P., & Sousa, R. (2017). PBL in the first year of an industrial engineering and management program: A journey of continuous improvement. *International Symposium on Project Approaches in Engineering Education*, *9*, 44–51.

Alves, A., Sousa, R., Moreira F, Alice Carvalho M, Cardoso E, Pimenta P, Malheiro M T, Brito I, Fernandes S, & Mesquita D. (2016). Managing PBL difficulties in an industrial engineering and management program. *Journal of Industrial Engineering and Management*, *9*(3). https://doi.org/10.3926/jiem.1816

Colombo, C. R., Moreira, F., & Alves, A. C. (2015). Sustainability Education in PBL Education: the case study of IEM. *Proceedings of the Project Approaches in Engineering Education*.
Fernandes, S., Alves, A. C., & Uébe-Mansur, A. (2021). Student-centered assessment practices: an integrated approach with project-based learning (PBL). *Handbook of Research on Determining the Reliability of Online Assessment and Distance Learning*, 213–242. https://doi.org/10.4018/978-1-7998-4769-4.CH009
Fernandes, S., Flores, M. A., & Lima, R. M. (2012a). Student assessment in project based learning. *Project Approaches to Learning in Engineering Education: The Practice of Teamwork*, 147–160. https://doi.org/10.1007/978-94-6091-958-9_10/COVER
Fernandes, S., Flores, M. A., & Lima, R. M. (2012b). Students' views of assessment in project-led engineering education: findings from a case study in Portugal. *Http://Dx.Doi.Org/10.1080/02602938.2010.515015*, *37*(2), 163–178. https://doi.org/10.1080/02602938.2010.515015
Graham, R. (2018). *The global state of the art in engineering education*. Massachusetts Institute of Technology
Guo, P., Saab, N., Post, L. S., & Admiraal, W. (2020). A review of project-based learning in higher education: Student outcomes and measures. *International Journal of Educational Research*, *102*. https://doi.org/10.1016/j.ijer.2020.101586
Helle, L., Tynjälä, P., & Olkinuora, E. (2006). Project-based learning in post-secondary education - Theory, practice and rubber sling shots. *Higher Education*, *51*(2). https://doi.org/10.1007/s10734-004-6386-5
Kolmos, A., & De Graaff, E. (2014). Problem-Based and Project-Based Learning in Engineering Education. *Cambridge Handbook of Engineering Education Research*, 141–160. https://doi.org/10.1017/CBO9781139013451.012
Leão, C. P., Abreu, M. F., Alves, A. C., & Fernandes, S. (2022). PBL tutoring dynamics in first-year of Industrial Engineering and Management Program. *International Symposium on Project Approaches in Engineering Education*, *12*. https://doi.org/10.5281/zenodo.7061886
Lima, R. M., Carvalho, D., Sousa, R. M., Alves, A., Moreira, F., Mesquita, D., & Fernandes, S. (2012). A project management framework for planning and executing interdisciplinary learning projects in engineering education. In *Project Approaches to Learning in Engineering Education: The Practice of Teamwork*. https://doi.org/10.1007/978-94-6091-958-9_5
Lima, R. M., Dinis-Carvalho, J., Campos, L. C. de, Mesquita, D., Sousa, R. M., & Alves, A. (2014). Projects with the Industry for the Development of Professional Competences in Industrial Engineering and Management. *Sixth International Symposium on Project Approaches in Engineering Education (PAEE'2014)*.
Lima, R. M., Dinis-Carvalho, J., Sousa, R., Arezes, P., & Mesquita, D. (2018). *Project-Based Learning as a Bridge to the Industrial Practice*. https://doi.org/10.1007/978-3-319-58409-6_41
Lima, R. M., Dinis-Carvalho, J., Sousa, R. M., Alves, A. C., Moreira, F., Fernandes, S., & Mesquita, D. (2017). Ten years of project-based learning (PBL) in industrial engineering and management at the University of Minho. In *PBL in Engineering Education: International Perspectives on Curriculum Change*. https://doi.org/10.1007/978-94-6300-905-8
Lima, R. M., Dinis-Carvalho, J., Sousa, R. M., Arezes, P., & Mesquita, D. (2017). Development of competences while solving real industrial interdisciplinary problems: A successful cooperation with industry. *Producao*, *27*(Specialissue). https://doi.org/10.1590/0103-6513.230016
Mesquita, D., Lima, R. M., Sousa, R. M., & Flores, M. A. (2009). The Connection between Project Learning Approaches and the Industrial Demand for Transversal Competencies. *Proceedings of the 2nd International Research Symposium on PBL (IRSPBL'2009)*.
Moreira, F., Mesquita, D., & Hattum-Janssen, N. (2011). The importance of the project theme in project-based learning: a study of student and teacher perceptions. *International Symposium on Project Approaches in Engineering Education (PAEE'2011): Aligning Engineering Education with Engineering Challenges*.
Moreira, F., & Sousa, R. M. (2008). Desenvolvimento de Protótipos de Sistemas de Produção no Âmbito da Aprendizagem Baseada em Projectos Interdisciplinares. In J. F. S. Gomes, C. C. António, & A. S. Matos (Eds.), *5º Congresso Luso-Moçambicano de Engenharia*. Edições INEGI.
Moreira, F., Sousa, R. M., Leão, C. P., Alves, A. C., & Lima, R. M. (2009). Measurement Rounding Errors in an Assessment Model of Project Led Engineering Education. *International Journal of Online and Biomedical Engineering (IJOE)*, *5*(6). https://doi.org/10.3991/ijoe.v5s2.1092
Sousa, R. M., Alves, A. C., Moreira, F., & Carvalho, D. (2014). *Lean games and hands-on approaches as learning tools for students and professionals*. https://repositorium.sdum.uminho.pt/handle/1822/31336
Sousa, R. M., Moreira, F., & Alves, A. C. (2014). *Active learning using physical prototypes and serious games*. https://repositorium.sdum.uminho.pt/handle/1822/30296

Is better academic performance in engineering synonymous with more entrepreneurial capacity? A cross-sectional study of the correlation between academic grades and business creation by graduates of Production Engineering at Universidade Federal do Rio de Janeiro

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Abstract

Some universities, especially in the United States and Europe, rank their graduates according to a weighted average of the grades obtained in academic activities – Grade Point Average (GPA), or Cumulative Performance Coefficient (derived from Coeficiente de Rendimento Acumulado – CRA in portuguese) in Brazil. It is common for companies to prefer better-ranked students for job openings, as well as in selective processes for master's or doctoral degrees. But what about entrepreneurial activity? Are entrepreneurs concentrated at the top of each class, or spread across the entire grade range? This work explores whether there is a correlation between entrepreneurial activity, measured by the creation of companies, and the academic performance of graduates, measured by the annual ranking in cohorts of each course. The sample used refers to all production engineering students who graduated from the Universidade Federal do Rio de Janeiro (UFRJ) over about 30 years, measuring their business activity through the anonymized database of the Brazilian Federal Revenue Service. The results have the potential to question whether the academic curriculum collaborates to form entrepreneurs and the role of academic excellence in entrepreneurial activity.

Keywords: Entrepreneurship; entrepreneurial activity; academic excellence.

1 Introduction

During last decades, entrepreneurship has gained attention in some developing countries, in addition to being seen as a possible solution to economic problems, due to its central role in the economic growth of developed countries (Nwankwo, Kanu, Marire, Balogun, & Uhiara, 2012). It is now seen as an engine room for economic growth, including its impact in several indicators, such as revenue generation, poverty alleviation and wealth creation (Adekiya & Ibrahim, 2016). Additionally, entrepreneurship has been considered as a key driver to employment and innovation (Urbano & Guerrero, 2013). Finally, Organization of Economic Cooperation and Development – OECD (2003) describes entrepreneurship as a process through which entrepreneurs create and grow enterprises to provide new products/services, or add value to products or services. From the above points, it is possible to deduce entrepreneurs are enterprising individuals who has the intention of creating and adding value to meet human needs (Adekiya & Ibrahim, 2016).

Additionally, entrepreneurial society refers to a society where entrepreneurship serves as the critical force driving economic growth, employment creation and competitiveness in global markets, and where institutions and policy have a focus on facilitating and generating entrepreneurial activity (Audretsch, 2009). In this society, the university is a key institution that catalyses regional economic and social development because it is a natural incubator that create new ideas and technologies (Urbano & Guerrero, 2013). However, not only generating new knowledge, but also facilitating spill overs that spur innovation, economic growth, job creation and competitiveness in global markets (Audretsch, 2009). The main outcome is to provide to the society graduates who become both job seekers and job creators (Schulte, 2004).

This study aims to analyse whether there is a correlation between entrepreneurial activity, measured by the creation of companies, and the academic performance of graduates, measured by the annual ranking in cohorts of each course.

2 Background

This section presents a literature review about principles related to main subject of the study: academic entrepreneurship and academic performance.

2.1 Academic entrepreneurship

Etzkowitz (2013) classifies the entrepreneurial university as an emergent phenomenon resulting from the working out of an 'inner logic' of academic development that previously expanded the academic enterprise from a conservator to an originator of knowledge. Furthermore, the entrepreneurial academic transition is the next stage in the development of a unique institution that incorporates and amplifies previous objectives.

Urbano and Guerrero (2013) show that several studies have tried to define academic entrepreneurship, but without consensus on the use of one specific definition. Since 1980, there has been a substantial rise in the commercialization of science and other forms of university technology transfer, both in USA and many countries in Europe and Asia (Siegel & Wright, 2015). These commercialization activities began to be known as "academic entrepreneurship" in some areas. This fact reinforces the relevance of a robust university ecosystem.

Because of this, the emergent view is based on to provide a wider social and economic benefit to the university ecosystem (Tatarlar & Turhan, 2021). As example, Roberts, Murray and Kim (2019) updated report about entrepreneurship and innovation at Massachusetts Institute of Technology (MIT). In this study, the authors highlight a wide range of infrastructure to support innovation broadly, but particularly entrepreneurship, has grown along a continuum from the earliest stages of commercialization and proof of concept to prototyping and venture creation at MIT over the past decade.

According to Siegel and Wright (2015), key elements of the broadened entrepreneurial university ecosystem include: (1) the rise of property-based institutions, such as incubators and accelerators; (2) substantial increase in the number of entrepreneurship courses; (3) establishment and growth of entrepreneurship centers; (4) a rise in the number of beginner entrepreneurs to stimulate commercialization and startup creation; and (5) a rapid increase in alumni support of this entrepreneurial ecosystem, including student business plan competitions.

Tatarlar and Turhan (2021) include diversity as another important factor to improve innovation performance of universities. These authors claim that there is a significant average correlation between overseas educational background and entrepreneurship aspects in universities. At MIT, foreign-born students play a relevant role as entrepreneurs and innovators as well as key trends in the alumni-founded ventures' industry composition, firm performance, and economic impact through job creation and sales (Roberts et al., 2019).

It is also important highlight that social and cultural approval by the society can contribute to the growth of entrepreneurial activity when the values of a given society reward entrepreneurship while disapproval impedes it (Adekiya & Ibrahim, 2016). When risk taking and supportive of uncertainty are cultural values, they are expected foster the creativity and innovation that underlies entrepreneurial activities (Hayton & Cacciotti, 2013). Further, for starting a new business many factors influence entrepreneurial intention, such as perceived desirability, feasibility, and entrepreneurial experience (Mitchell et al., 2002).

2.2 Academic performance

Academic performance can be seen as a result of several inputs. Usually, some factors are considered as important to a good student performance, such as student engagement, learning styles, learning environment and teaching activities.

Learning in a structured educational setting may be thought of as a two-step process involving the reception and processing of information. A learning-style model classifies students according to where they fit on a number of scales pertaining to the ways they receive and process information. (Felder Richard M. & Silverman Linda K., 1988). Learners have their preferred ways of perceiving, organizing and retaining information that are distinct and consistent (Chou & Wang, 2000). Then, individuals have their preferred methods of interacting with, taking in, and processing stimuli and information when they learn (Li, Yu, Liu, Shieh, & Yang, 2014).

Li et al claim (2014) the best way to assist students is to create a harmonious learning environment, and to use teaching methods that are suitable to the students' learning styles. Learning style is an important consideration when planning for effective and efficient instruction and learning (Childress & Overbaugh, 2001). Zhang and Lambert (2008) state that a better understanding of learning styles can be beneficial to both teachers and students.

During last decades, engineering education has been transformed to match new students' characteristics. A common point among the modernization movements is the recommendation to place the student at the center of the learning process, which drives the increasing use of active learning techniques (Hartikainen, Rintala, Pylväs, & Nokelainen, 2019). Student-centered strategies increase student engagement, which is linked to teaching effectiveness. The positive results have already been widely explored (Burke & Fedorek, 2017; Cho, Mazze, Dika, & Gehrig, 2015; Prince, 2004).

Finally, academic performance is usually associated to an index, as Grade Point Average (GPA). This paper will use this index as the score that summarize effectiveness of students' learning.

3 Methodology

The main goal of this paper is to analyse whether there is correlation between entrepreneurial capacity and academic performance. Entrepreneurial capacity will be measured by alumni-founded companies (AFC). These companies have alumni between their founders and can be seen as an actual result of entrepreneurial attitude from students.

3.1 Method to assign a company as AFC

To establishing the method to sort alumni-founded companies, two databases were used in this study: (1) a de-identified open database from the Brazilian Internal Revenue Service – IRS, and (2) university internal system of student registration. Since student data is identified, special permission was obtained for this study. Individuals cannot be identified because all results are provided as aggregates.

The first step is to list all companies that have alumni as partners. This first list may contain multinational companies that have attributed legal responsibility to directors (alumni included), since these records are filed together with the companies' corporate data. In addition, a large company can create a second company, which has alumni among its partners. In this case, the company could not be considered an AFC. By the other hand, if a company has a legal entity between its partners, but the entry of this legal entity occurs after first moment, it is probable that an acquisition – total or partial – happened.

Then, to be classified as AFC, two main criteria must be followed: (1) When the company does not have a legal entity as a partner, an alumni must have joined the company as a partner up to 30 days after company's starting date; and (2) If the company does have a legal entity as a partner, it must have joined the company after day 30 of company's starting date.

3.2 Pilot sample

The approach used in this paper quantifies entrepreneurial activity at Universidade Federal do Rio de Janeiro (UFRJ) and uses its Industrial Engineering program alumni as a first attempt to a demographic study of UFRJ's alumni-founded companies.

Initial population of this study consisted of 2363 alumni who graduated between 1990 and 2020. From 1990 to 2000, around 60% of this population had either missing or invalid ID document number registered in the database, since only by 2001 the university started an integrated institutional data system, gathering data from different and independent internal sources. Then, only 1800 individuals from the original list were used in the companies search. Table 1 shows how is the distribution of graduates over decades.

Table 1. Graduate distribution over decades

Decade	Number of graduates
1990	348
2000	737
2010	684
2020	31

4 Results and discussion

In this section, the results achieved in the research will be shown, in addition to the analyzes on them. Initially, Table 2 shows the GPA distribution of graduates over the decades.

Table 2. GPA distribution of graduates over the decades

Decade	GPA >= 9.0	9.0 > GPA >= 8.0	8.0 > GPA >= 7.0	7.0 > GPA >= 6.0	6.0 > GPA
1990	1.1%	18.7%	52.6%	20.7%	6.9%
2000	2.2%	35.4%	43.6%	14.4%	4.5%
2010	1.5%	35.2%	45.3%	13.2%	4.8%
2020	0.0%	22.6%	58.1%	19.4%	0.0%
Total	1.7%	31.9%	46.2%	15.2%	5.0%

It is observed that the percentage of graduates with a GPA equal to or greater than 9.0 is much lower than the other ranges, which may indicate difficulty in completing the program. When comparing the last three decades, it is possible to notice that the decades of 2000 and 2010 present similarities in the GPA ranges, except for GPA above 9.0. However, the last decade shows a reduction in the GPA range from 8.0 to 9.0 and a higher concentration between 7.0 and 8.0, compared to those two previous decades.

In the population of 1800 graduates analyzed, there is a moderate variation of GPA over the years. Figure 1 shows how this variation occurs, and it is possible to identify four cohorts:

- Cohort 1: GPA >= average + standard deviation
- Cohort 2: Average + standard deviation > GPA >= Average
- Cohort 3: Average > GPA >= Average - standard deviation
- Cohort 4: Average – standard deviation > GPA

In other words, cohort 1 is above the green line, cohort 2 is between green and blue lines, cohort 3 is between orange and blue lines, and cohort 4 is below the orange line.

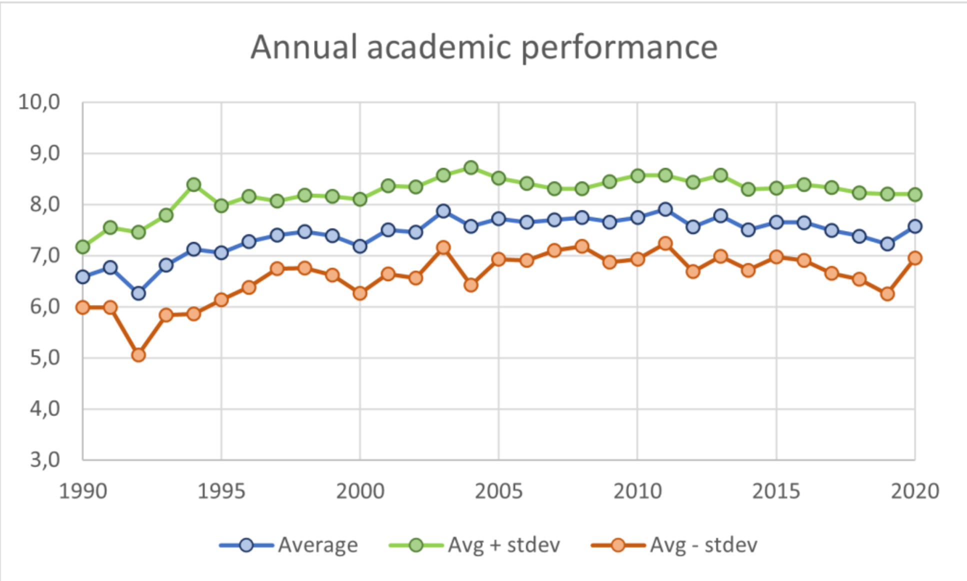

Figure 1. Annual academic performance, with 4 cohorts

Considering this population, there was the creation of 155 companies classified as AFC, which were created by 125 graduates. Table 3 shows the distribution of these 125 entrepreneurs, according to their decade of graduation.

Table 3. Entrepreneurs' distribution over decades of graduation

Decade	Number of entrepreneurs	Ratio between entrepreneurs and graduates
1990	15	4.3%
2000	40	5.4%
2010	70	10.2%
2020	0	0.0%

The last line of Table 3 shows that no graduate (from the group considered) from 2020 onwards founded an AFC. This can be explained by the short observation time so far, combined with a period of global economic slowdown, due to the COVID-19 pandemic and the conflict between Russia and Ukraine.

It is also observed that the number of entrepreneurs (second column) over the decades is strictly increasing. This fact can be explained by several factors, such as: (i) increase in the number of graduates with complete data in the academic system, which increases the effectiveness in the search for founded companies; (ii) period of economic growth in Brazil, linked to the stabilization of the currency and fight against hyperinflation; and (iii) ongoing technological revolution, which allows companies to be created with less investment than in the predominantly industrial phase.

To calculate the correlation between GPA and entrepreneurial activity, each entrepreneur had the activity indicator value 1, while the others had the value 0. Thus, the correlation found was -0.01. Another attempt was to replace the absolute value of the GPA with its range, as shown in the tables 2 and 5. Thus, the correlation was -0.003. Aggregating graduates in cohorts by annual academic performance, the correlation with entrepreneurial activity is 0.01. These values suggest that does not exist relevant correlation between GPA and entrepreneurial capacity.

To analyze how entrepreneurs are distributed in cohorts by annual academic performance, Table 4 is exhibited below.

Table 4. Entrepreneurs versus annual academic performance cohorts

Cohort	Number of graduates	Number of entrepreneurs	Ratio between entrepreneurs and graduates
1	241	9	3.73%
2	754	61	8.09%
3	544	37	6.80%
4	267	18	6.92%

It is possible to see that the rate of entrepreneurs is not directly linked to the annual cohort. In addition, the lowest rate of entrepreneurs is exactly in the cohort with the best academic performance. One possible explanation, which could be further investigated in future studies, is the fact that students in this group may have a higher tendency to pursue an academic career. This fact is yet another indication of the lack of connection between the indicators.

The distribution of entrepreneurs in the GPA ranges, both in absolute numbers and relative to the total number of graduates in each range, is presented in table 5.

Table 5. Entrepreneurs versus GPA

GPA	Number of entrepreneurs	Ratio between entrepreneurs and graduates
GPA >= 9.0	2	6.67%
9.0 > GPA >= 8.0	43	7.44%
8.0 > GPA >= 7.0	56	6.64%
7.0 > GPA >= 6.0	15	5.21%
6.0 > GPA	9	9.28%
Total	**125**	**6.80%**

The first observation in Table 5 highlights the percentage of approximately 6.8% of entrepreneurs in the considered program. This rate is almost the same in all GPA ranges, except in the last row of the table, where the number shows a jump of almost 3 percentage points, or 50% relative.

This is one more indication that entrepreneurial capacity is not directly linked to academic performance, due to two factors: in addition to not showing large fluctuations between GPA ranges, the range with the lowest GPA values has the highest percentage of entrepreneurs. Table 5 shows how entrepreneurs are distributed over the decades and in the GPA ranges.

Table 6. Ratio between entrepreneurs and number of graduates over decades of graduation

Decade	GPA >= 9.0	9.0 > GPA >= 8.0	8.0 > GPA >= 7.0	7.0 > GPA >= 6.0	6.0 > GPA
1990	0.0%	0.6%	1.4%	1.4%	0.9%
2000	0.0%	1.9%	2.2%	0.8%	0.5%
2010	0.3%	3.9%	5.1%	0.6%	0.3%
2020	0.0%	0.0%	0.0%	0.0%	0.0%

It is possible to verify that the ranges with the highest concentration of entrepreneurs change from one decade to another. When looking at the last two complete decades, which have the highest volume of graduates, entrepreneurs are most concentrated in the GPA column between 7.0 and 8.0.

The evidence presented is limited, both by the size and scope of the sample, and by the gap in older data. However, they suggest that the relationship between academic performance and entrepreneurial ability may not be as strong as it is with employability, for example.

Despite the limitations, it is indisputable that the ranges with the highest GPA values do not have a high concentration of entrepreneurs, neither decade after decade, nor in the accumulated total. This fact reinforces the suspicions of the lack of correlation between the two analyzed indicators.

5 Conclusion

This work aimed to investigate whether there is a correlation between academic performance and entrepreneurial capacity. For this, a sample of around 2350 graduates in Industrial Engineering at the Universidade Federal do Rio de Janeiro, distributed over about 30 years, was analyzed.

Entrepreneurial activity is an important factor for economic growth, both regionally and nationally, as can be seen in developing countries. In this way, the university needs to update itself in the preparation of individuals who are able to identify opportunities and apply their knowledge.

The first analyzes presented in this study indicate that there is no direct correlation between entrepreneurial capacity and academic activity. Although studies need to be deepened and extended, these indications serve as a warning for deeper investigation and possible adjustments in higher education courses, with the aim of promoting the update mentioned above.

As future work, it is suggested that the studies be deepened with other courses, in addition to considering the size of the companies classified as AFC, to prevent the analyzes from being contaminated by companies without employees, for example. This type of company may indicate that the legal entity was created to camouflage the hiring of an individual.

6 References

Adekiya, A. A., & Ibrahim, F. (2016). Entrepreneurship intention among students. The antecedent role of culture and entrepreneurship training and development. *International Journal of Management Education*, *14*(2), 116–132. https://doi.org/10.1016/j.ijme.2016.03.001

Audretsch, D. B. (2009). The entrepreneurial society & the role of the University. *Journal of Technology Transfer*, *34*(2), 245–254.

Burke, A. S., & Fedorek, B. (2017). Does "flipping" promote engagement?: A comparison of a traditional, online, and flipped class. *Active Learning in Higher Education*, *18*(1), 11–24. https://doi.org/10.1177/1469787417693487

Childress, M. D., & Overbaugh, R. C. (2001). The relationship between learning style and achievement in a one-way video, two-way audio preservice teacher education computer literacy course. *International Journal of Educational Telecommunications*, *7*(1), 57–71. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2001-05264-002&site=ehost-live%0Ahttp://childrem@emporia.edu

Cho, C.-S., Mazze, C. E., Dika, S. L., & Gehrig, G. B. (2015). Enhancing Construction Education: Implementing Habitat for Humanity Projects as Service-Learning for Construction Materials. *International Journal of Construction Education and Research*, *11*(1), 4–20. https://doi.org/10.1080/15578771.2014.915274

Chou, H. W., & Wang, T. Bin. (2000). Influence of learning style and training method on self-efficacy and learning performance in WWW homepage design training. *International Journal of Information Management*, *20*(6), 455–472. https://doi.org/10.1016/S0268-4012(00)00040-2

Etzkowitz, H. (2013). Anatomy of the entrepreneurial university. *Social Science Information*, *52*(3), 486–511. https://doi.org/10.1177/0539018413485832

Felder Richard M., N. C. S. U., & Silverman Linda K., I. for the S. of A. D. (1988). Learning and Teaching Styles in Engineering Education. *Engr. Education*, *78(7)*, 674–681.

Hartikainen, S., Rintala, H., Pylväs, L., & Nokelainen, P. (2019). The concept of active learning and the measurement of learning outcomes: A review of research in engineering higher education. *Education Sciences*, *9*(4), 9–12. https://doi.org/10.3390/educsci9040276

Hayton, J. C., & Cacciotti, G. (2013). Is there an entrepreneurial culture? A review of empirical research. *Entrepreneurship and Regional Development*, Vol. 25, pp. 708–731. https://doi.org/10.1080/08985626.2013.862962

Li, Y. S., Yu, W. P., Liu, C. F., Shieh, S. H., & Yang, B. H. (2014). An exploratory study of the relationship between learning styles and academic performance among students in different nursing programs. *Contemporary Nurse*, *48*(2), 229–239. https://doi.org/10.1080/10376178.2014.11081945

Mitchell, R. K., Smith, J. B., Morse, E. A., Seawright, K. W., Peredo, A. M., & McKenzie, B. (2002). Are entrepreneurial cognitions universal? Assessing entrepreneurial cognitions across cultures. *Entrepreneurship Theory and Practice*, *26*(4), 9–32.

Nwankwo, B. E., Kanu, G. C., Marire, M. I., Balogun, S. K., & Uhiara, A. C. (2012). Gender-role orientation and self-efficacy as correlates of entrepreneurial intention. *European Journal of Business and Social Sciences*, *1*(6), 9–26.

OECD. (2003). *Entrepreneurship and local economic development: programme and policy recommendations*. OECD Paris.

Prince, M. (2004). Does Active Learning Work? A Review of the Research. *Journal of Engineering Education*, *93*(3), 223–231. https://doi.org/10.1002/j.2168-9830.2004.tb00809.x

Roberts, E. B., Murray, F., & Kim, J. D. (2019). Entrepreneurship and innovation at MIT: Continuing global growth and impact - An updated report. *Foundations and Trends in Entrepreneurship*, *15*(1), 1–55. https://doi.org/10.1561/0300000093

Schulte, P. (2004). The entrepreneurial university: a strategy for institutional development. *Higher Education in Europe*, *29*(2), 187–191.

Siegel, D. S., & Wright, M. (2015). Academic Entrepreneurship: Time for a Rethink? *British Journal of Management*, *26*(4), 582–595. https://doi.org/10.1111/1467-8551.12116

Tatarlar, C. D., & Turhan, R. (2021). Does diversity make a difference? The effect of profile and diversity of academics on innovation performance of Turkish universities. *International Journal of Contemporary Economics and Administrative Sciences*, *11*(2), 314–338.

Urbano, D., & Guerrero, M. (2013). Entrepreneurial Universities: Socioeconomic Impacts of Academic Entrepreneurship in a European Region. *Gender and Society*, *27*(1), 40–55. https://doi.org/10.1177/0891242412471973

Zhang, H., & Lambert, V. (2008). Critical thinking dispositions and learning styles of baccalaureate nursing students from China. *Nursing and Health Sciences*, *10*(3), 175–181. https://doi.org/10.1111/j.1442-2018.2008.00393.x

Flipped Classroom Teaching of Mobile Robotics[3]

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Abstract

The field of mobile robotics is characterised by the presence of large sources of errors in both sensor and actuator models. As such, it requires advanced knowledge in the representation of uncertainty in dynamic systems and it is seldom approached by undergraduate level courses. Moreover, the vast richness of robot and environment imperfections cannot be aptly captured by simulations. We propose a new approach to teach mobile robotics in undergrad classes by adopting a flipped classroom. The theoretical aspects of mobile robotics are provided to the students as reading material and video lectures to be studied before the classroom. In the classroom the students apply their newly acquired knowledge by making a mobile robot perform specific tasks. A mobile robot was developed specifically for this flipped classroom with differential steering, inertial sensors and a digital camera. The lectures cover topics such as Bayesian State estimation, Computer Vision, Kalman Filters, Particle Filters and Monte Carlo Navigation. This new approach applied to students of the Mechatronics Engineering Program of the Escola Politécnica da Universidade de São Paulo. Students' evaluation was very positive.

Keywords: Mobile Robotics; Flipped Classroom; Course Evaluation

1 Mobile Robotics in Higher Education

Conceived as a multidisciplinary field, robotics integrates several academic departments, such as mechanical engineering, electrical and electronic engineering, and computer science. Although universities have been developing teaching methods to present the most relevant contents in this field, a structured curriculum has not yet been fully consolidated (Shibata et al. 2021). Courses generally include experimental proposals, enabling students to acquire knowledge through practical activities, for example robot contests (Soto, Espinace, and Mitnik 2006). These activities improve motivation in incoming students and deepen concepts in more advanced undergraduate students.

An emerging trend in higher education is the "flipped classroom" methodology (Talbert 2017). Lectures are moved online and classroom time is used for laboratory experimentations and demonstrations. This strategy was tested on Rose-Hulman Institute of Technology, an undergraduate engineering college from Indiana, USA, where some challenges constrained the development of the course, such as faculty workload, classroom size and availability of robots (Berry 2017).

Equally important for structuring a robotics curriculum is to adapt the approach according to the audience of the course. Topics covered may differ depending on interests and background knowledge of students. Courses for engineering programs tend to approach more hardware aspects: what a robot is made of, how it is built, which activities it can execute or how it is controlled. In opposition, courses for computer science programs tend to approach more software aspects: how can robots perceive, learn, communicate, or behave (Kirandziska and Ackovska 2017). The incorporation of laboratory exercises, in combination with theory and computational simulations, at the Saints Cyril and Methodius University (Skopje, Macedonia), has resulted in higher average grades from computer science students. Besides achieving better grades, other positive effects include the increase in complexity of the projects and the increase in confidence from students to choose to build their own robots, rather than using the ones already available in the laboratory.

2 The “PMR3502 - Elementos de Robótica” course

2.1 Previous Experiences

PMR3502 - “Elementos de Robótica” (“Robotics Elements”) is a 50 hour course on robotics, offered to the 5th year undergraduate students of the Mechatronics Engineering program at the Escola Politécnica da Universidade de São Paulo. Prior to 2019 the course program consisted solely of industrial robots. Specifically, topics such as different manipulator topologies, cinematics, Denavid-Hatenberg parameters, dynamics and control. The course included 12 hours of practical activities with a Kuka industrial robot.

In 2019 a first attempt was made to introduce the content of mobile robots. Half the course was allocated to mobile robots. The goal was to teach tasks of mobile robot navigation, exploration and mapping. Mobile robots must perform those tasks in the presence of uncertainties, caused by actuators and sensor errors. The adopted theoretical framework for dealing with uncertainties is that of probabilistic robotics (Burgard, Fox, and Thrun 2005). The field of probabilistic robotics is strongly related to the field of random dynamic systems, a field that not often taught at undergraduate level. As such, the new course had to include a review of multivariate random variables, an introduction to random linear dynamic systems, Bayesian probability and recursive state estimation. The actual mobile robotics content included sensor fusion, environment mapping with known pose, localization with known environment map and Simultaneous Location and Mapping (SLAM). The students were graded using homework assignments, based on simulated robots. They were provided with robot control actions and simulated sensorial inputs and were tasked to reconstruct robot trajectories and environment maps. Those assignments were performed on jupyter-notebooks. A similar approach was independently developed by (Ruiz-Sarmiento, Baltanas, and Gonzales-Jimenez 2021).

To enhance the *metacognitive aspect* (Zimmerman 2002) of learning, it is desirable to not only teach the concepts, but show to the students that they are indeed learning something useful. Unfortunately, simulated data is a poor substitute for actual sensor and actuator noise from physical robots. Considering the essential role that uncertainties play in mobile robotics, the course was found lacking in this aspect.

Meanwhile, tasks involving actual mobile robots involve many additional complexities such as mobile power supplies, remote wireless communication and minutiae of embedded operating systems. While pertinent, those complexities add to the already very loaded syllabus of probabilistic robotics. Moreover, the successful performing of even simple tasks on a mobile robot requires the perfect coordination of every single one of those elements. Instead of engaging, the introduction of physical robots may frustrate and confuse the students and keep them away from the knowledge that was meant to be introduced in the first place.

The Flipped Classroom arises as a perfect solution to this conundrum. Since every single assignment is performed in the presence of experienced tutors (Talbert 2017), they can guide students through bumps presented by technical details, while keeping alive the challenges of core mobile robotics concepts.

2.2 Outline of the Course Reformulation

Considering the above, it was decided for a reformulation of the content of mobile robotics in PMR3502. The following goals were defined:

- The course would keep its focus on the probabilistic aspects of mobile robotics. The main task should be to reconstruct probabilistically the state of the robot and its environment.
- Every single collective learning experience, (the so-called “classroom time”) should be in the form of experiences with a physical robot. There would be no pure theoretical exercises nor problems with synthetic data. All data should be collected by the students in the classroom with their own robot.
- The experiments should be performed by small groups of students (between 2 and 3) and guided by experienced tutors shared between groups.
- As per the tenets of “Flipped Classroom”, the individual learning experiences (“homework assignments”) would be dedicated to studies of the underlying theoretical foundations of mobile robotics. The course would provide this content in the form of video lectures and a course pack.

3 Robot Description

3.1 Requirements

A core aspect of the new course is the actual robots that the students will interact with. The robot should:

- Be fully manoeuvrable in the 2d plane.
- Be untethered. That means that it should be self-sufficient in power.
- Have low latency[5] remote communication capabilities.
- Have remote sensing, that is, it should be able to detect environment features at distance.
- Have measurable control actions.
- Have enough processing power to solve localization and mapping problems with low latency[1].

The decision for a "Flipped Classroom" approach signifies that the supplementary material, with the theoretical aspects of mobile robotics, should be in electronic, distributable form. This is an opportunity to share the course with other teaching institutions. Moreover, anyone can purchase the robots and reproduce the required environments at home, following the lectures and thus complete the course. It was decided that the robot should be assembled by easily accessible components and its design should be very cost aware.

3.2 About RoboCore

Considering those requirements, the PMR3502 team decided to look for the help of a local supplier, "RoboCore Tecnologia". RoboCore is a brazilian company specialised in the creation of electronics and robotics kits for schools and universities. It was founded in 2008 and its headquarters is in Santana de Parnaíba, São Paulo, Brazil. Since its foundation, RoboCore has been organising robotics events where students and enthusiasts compete with their projects in categories such as robot sumo, line follower and chasing robots, robot soccer, robot trekking and combat. RoboCore produces their own electronics and robotics hardware. They have been helping teachers all over the country to expand their tools to create immersive experiences and ludic material for the classroom.

3.3 Final Design

The design was based on the preexisting "Falcon" platform by RoboCore (RoboCore 2018). The "Falcon" platform is a small mobile platform measuring 161x178mm with two motorised rubber wheels and one passive rolling sphere arranged in a tricycle configuration. Steering is differential.

The configuration Includes:

- Two rubber wheels driven by 5V DC electric motor-reductors with polymeric gearing in a differential steering configuration. This allows for a fully steerable nonholonomic robot.
- One 5V dual channel h-bridge module L9110. The h-bridges can be driven by Pulse-Width Modulation (PWM) signals. A single module is enough to drive both electric motors.
- One microelectromechanical (MEMS) 6-dof Inertial Measurement Unit mcu6050. The IMU is used to measure control actions. The mcu6050 has an i²c serial interface and an external interrupt signal.
- One USB Logitech 930e webcam. This provides the remote sensing capabilities for the robot. This webcam was selected because it is widely available and has a relatively wide field of view of 90 degrees. Its electronic rolling shutter is also fast enough that the frames captured while the robot is in motion aren't distorted significantly.
- One 4GB Raspberry Pi 4 microcomputer. That's a single-board computer with a 64-bit quad-core processor cortex-A72 (ARM v8) clocked at 1.5GHz. It has 2.4 GHz and 5.0 GHz IEEE 802.11ac wireless, USB interfaces, an i²c interface and General Purpose I/O with two hardware PWM channels.
- One USB power bank geonav PB20KBK. This is an USB power bank with 20.000 mAh and 18W.

This final configuration satisfies nearly all the requirements from section 5.1. The main shortcomings currently are the lack of direct wheel action measurement (although the use of an IMU allows for interesting EKF

[5] The authors ask here for a bit of leniency on the definition of "low latency". There was no pretension of "hard real-time SLAM". An honest definition would be"fast enough to not annoy the students".

applications) and an expensive Webcam. Another significant although temporary limitation is the worldwide supply shortage of the Raspberry Pi 4B model in 2022. This severely limited the adoption of this robot outside this course. This supply limitation is currently being normalised (Upton 2022).

4 Additional Materials and Class Environment

4.1 Individual Space Material

As mentioned in section 3.1, students have their first contact with the studied subjects in their individual space. For that they must be supplied with study material. In the new robotics course, this material is in the form of a course pack[6] and short (about 5 min) video lectures. Prior to each class, students are required to read the relevant section from the course pack and follow video lectures. The course pack and video lectures must, beyond preparing the students for classes, also present more universal content of mobile robots, with different robot configurations, actuators, sensors and algorithms. Students that want to read further on the subject are directed to supplementary material, specifically, (Burgard, Fox, and Thrun 2005) for reading on the theoretical aspects of probabilistic mobile robotics.

4.2 Physical Infrastructure

Robots themselves are covered in detail in section 5.3. Additionally, the classroom has specific environments for the diverse tasks of the robot. To allow for an easy replication of the course outside the University, those environments are designed so they can be built using printed images on simple a4 paper. Moreover, the classroom itself has desks arranged in a layout suitable for the work of small groups (2-3 students). There is also enough floor space for robot manoeuvring and building environments. The classroom has networked computers (again, one per group). While from our experience many students will bring their own portable computers, it is useful to have computers with known configuration at hand. Those computers have an up-to-date Linux configuration. They are mostly used to remotely access the robot. through web browser and ssh terminal access. Finally, the classroom has a wifi network. The Raspberry Pi microcomputers on the robots are "headless", that is, they have no screen connected to them. To facilitate their remote access, the network dynamic ip service is configured with the MAC address of each Raspberry Pi to assign preprogrammed addresses. Moreover, a domain name service assigns preconfigured names to each of those addresses. Those names are printed on labels stuck on the corresponding Raspberry Pi board.

4.3 Virtual Infrastructure

The course is supported by a substantial virtual infrastructure. The heavy lifting of communications between the tutors and students are managed by a USP moodle installation. This includes distribution of the course pack, announcements from the course management, discussion forum and assignment submissions. Video lectures are hosted on a specific video-lectures portal from USP. Source code sharing is supported by a USP GitLab server. The use of locally hosted services avoids enforcing students to enrol on third-party providers.

5 Course Program

Classes involve practical tasks with robots. Students are divided into small groups (2-3 students). Groups are fixed for the whole course and each is assigned one robot. Prior to each class they must study the relevant supplementary material. During class they must work within their group to achieve a specific task with their robot. At the end of the class they must submit the results of their tasks. Grades are based on those submissions. The course is divided into 8 lectures.

[6] https://d229kd5ey79jzj.cloudfront.net/1460/Aprendendo_Rob_tica_M_vel_na_Pr_tica-3-1.pdf

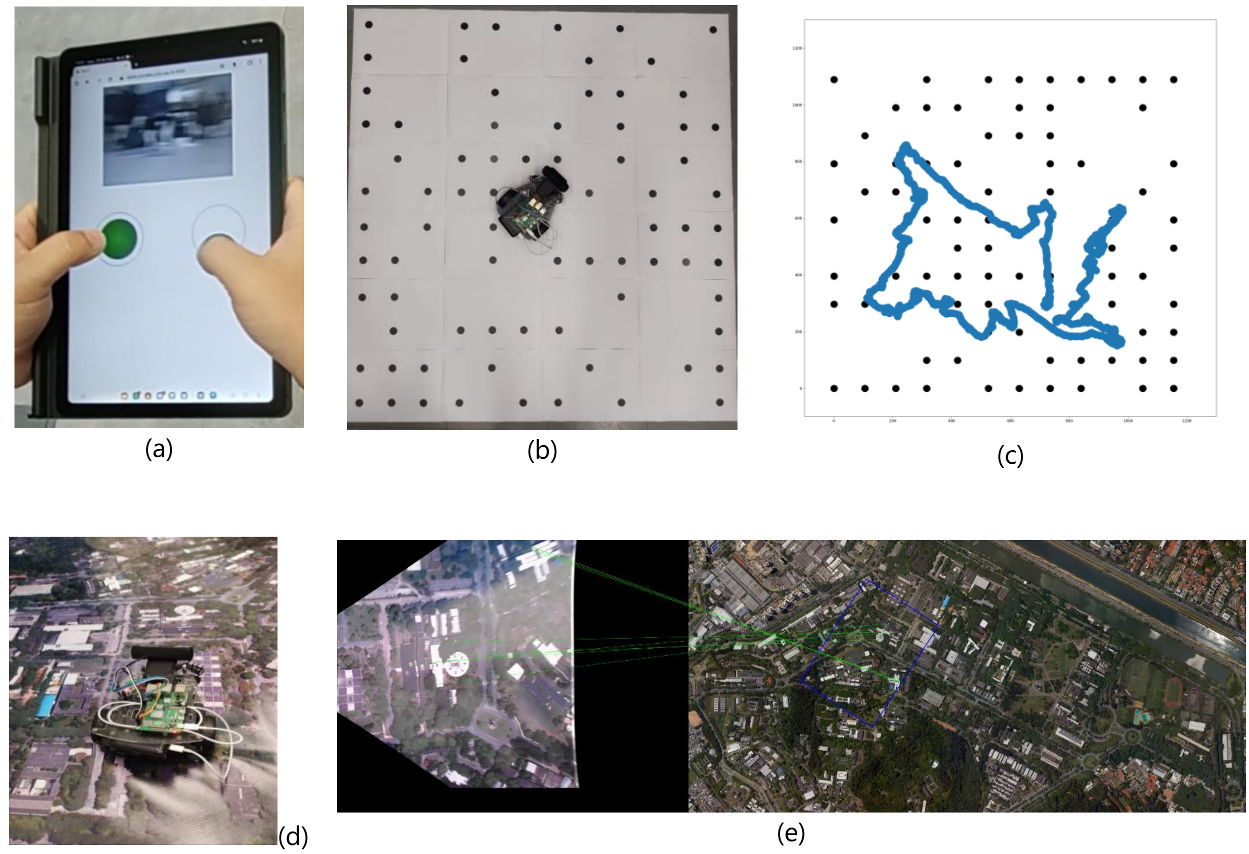


Figure 1. (a) Robot Teleoperation. (b) Robot on "black dots" map. (c) Robot Trajectory reconstructed by Monte Carlo Navigation. (d) Robot over satellite photo. (e) Feature Matching and robot localization.

The program is:

1. Course introduction: This lecture is the "odd one", as it is the only one that deviates from the "Flipped Classroom" and practical activities model. During this classroom the students are presented with the course format. General principles of probabilistic mobile robotics are introduced.
2. Robot Assembly and Teleoperation: This is the first fully "Flipped" class. The idea here is to familiarise the students, many of those having no previous contact with a Linux OS, with their equipment. The students receive their robots fully disassembled. They must assemble their robots and perform its initial setup. During this they must achieve several functional tests to ensure correct assembly and setup. Finally, they must complete a "teleoperation" application (See Figure 3-a).
3. IMU calibration and Extended Kalman Filter: The students must calibrate their IMU estimating gains and bias. They learn parameter estimation and i²c communications. Once they are done, they must apply sensor fusion to their 6dof IMU to estimate dynamic robot tilt. The sensor fusion technique applied is the Extended Kalman Filter.
4. Camera Calibration, Augmented Reality and Perspective Transform. The students are introduced to the pinhole camera model. They must identify their intrinsic and extrinsic camera parameters. Then they must replicate the 3d projection model by drawing virtual objects with known world coordinates over a captured scene. Finally, they must invert the projection model by recovering an undistorted image of a picture placed in the ground before the robot.
5. Visual Feature detection and description. The students are introduced to the concept of features in Computer Vision. They must implement Laplacian and Shi-Tomasi based corner detectors. They are then introduced to descriptors of features such as Scale Invariant Feature Transforms (SIFT) and Speeded Up Robust Features (SURF).

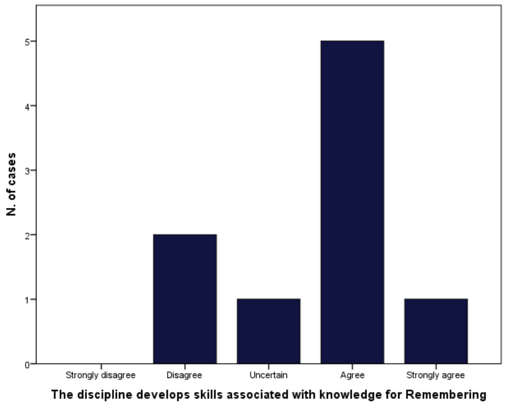
6. Feature Matching and Visual Odometry: Students must implement an online feature detection, description and matching. They are introduced to the Random Sample Consensus (RANSAC) algorithm to detect affine transforms between matched sets of features. They must implement a simple visual odometry system to reconstruct robot trajectories (see Figure 3-(d) and 3-(e)).
7. The "Kidnapped Robot Problem": This is the first of a two-part construction of a Monte Carlo Navigation System. The camera is now being used to emulate simple beam sensors, such as ultrasonic rangers and LIDAR The robots are placed over a plain white floor with featureless black dots, mimicking the simple response of beam sensors (see Figure 3-(b)). The students must implement a sensorial model for the particle filter.
8. Monte Carlo Navigation: The students now will complete their Monte Carlo Navigation System. They must use data from the IMU to feed a cinematic model of the robot and build the prediction model for the Particle Filter. They finally reconstruct robot pose and velocity (see Figure 3-(c)).

6 Student Feedback

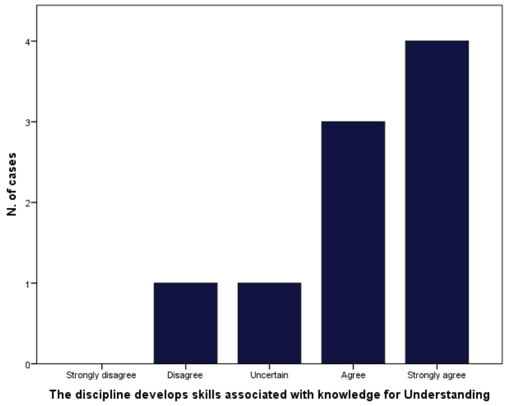
The student feedback was obtained by means of an anonymous questionnaire which was organised in 5 blocks, the first block allowed for the optional inclusion of the email and the year of course completion. The last block contained open questions where the students were free to include their opinions and suggestions about the course. The three intermediate blocks consisted of questions about the learning experience, the instructor and the contents of the Mobile Robotics course. The answers were rated with five possible options, similar to a Likert scale, depending on the question. For questions about the learning experience the students could rate each question as: Weak, Moderate, Satisfactory, Very good or Excellent. For the questions related to instructor ability and course contents, there was a sentence and the students had to rate the level of agreement: Strongly disagree, Disagree, Uncertain, Agree or Strongly agree. For statistical analyses the responses were converted to numeric values from 1 to 5.

The data analyses included a description of relevant questions and a comparison of the level of learning at the beginning and at the end of the course. It has also presented the perception of the course content in the framework of Bloom's taxonomy (see Figure 4). The opinion of the students about the time available and the amount of knowledge are also presented (Figure5). Finally, a paired t-test comparison was performed between the level of skill/knowledge at the beginning and at the end of the course and to the level required to complete the course, in order to assess the learning perception.

The course was clearly oriented towards application, and the students clearly perceived it, as can be seen in Fig. 4 (d). It is interesting to note that despite the fact that the course was not specifically oriented towards fostering creativity, this aspect was highly valued by the students see Fig. 4 (e). The course load was perceived as high by the students, who considered that the content was not appropriate to the time available (3 hours/week per half a semester). However, the structure of the course content and planning, the dedication and the final perception about the learning was positive (see Fig. 5).



(a)



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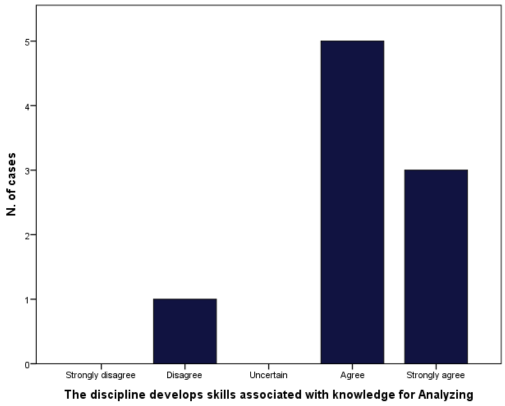
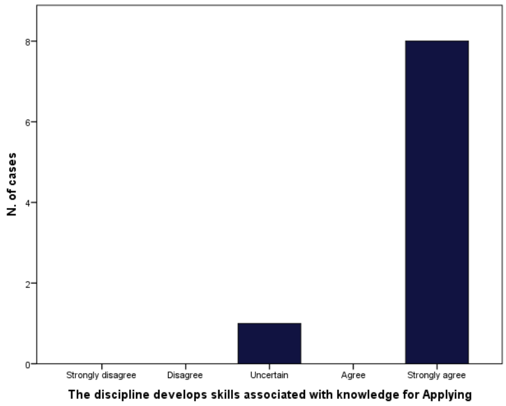
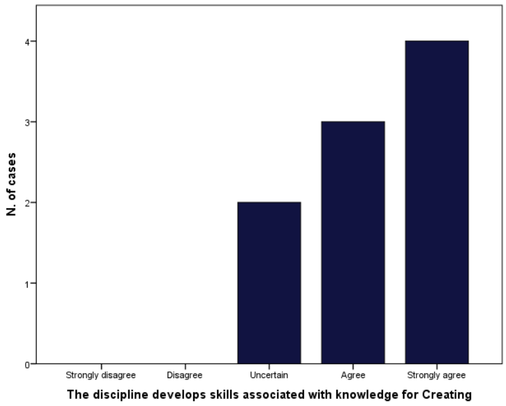


(c)



(d)



(e)

Figure 4. Student's opinion about the skills developed during the course related to Bloom's taxonomy

The paired t-test comparison revealed significant differences between the level of skill/knowledge at the beginning and at the end of the course ($t=-5.488$, $p=0.001$). However, there was no significant difference between the level of skill/knowledge at the end of the course and the level required to complete the course ($t=-0.263$, $p=0.799$), indicating that the participants learnt what they expected.

Finally, there were some useful open comments about the course. The students reported that the experience of building the robot from scratch was "amazing" and allowed them to "deal with real-life difficulties" and "practical applications". This is critical for final year students, as it was our case, and this course seems to fit with their expectations. A negative point mentioned by the students was that the time of the course was not sufficient. In this respect, the number of lecture hours per week is not easy to change. The time constraints are present in every engineering project and it is important to teach the final year students to deal with it.

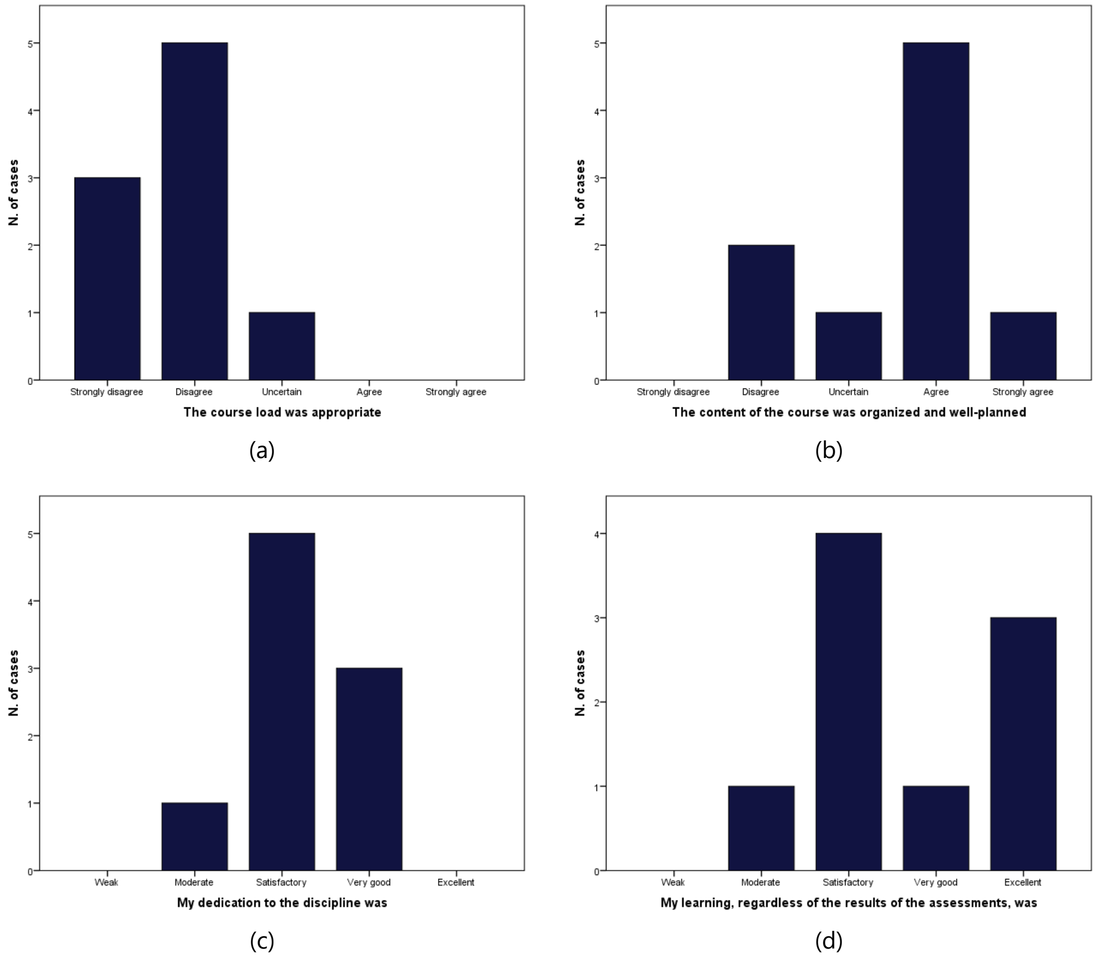


Figure 5. Opinion of the students about course load, dedication, learning and objectives

7 References

Berry, C. A. 2017. "Lessons Learned Flipping a Mobile Robotics Course." *Journal of Online Engineering Education* 8, no. 2 (December).

Burgard, Wolfram, Dieter Fox, and Sebastian Thrun. 2005. *Probabilistic robotics*. N.p.: MIT Press.

Kirandziska, Vesna, and Nevena Ackovska. 2017. "Robotics course - A challenge for computer science students." *IEEE Global Engineering Education Conference (EDUCON)*, 951-954. 10.1109/EDUCON.2017.7942963.

RoboCore. 2018. "Plataforma Robótica Falcon 1.2," Manual de Montagem. São Paulo. https://d229kd5ey79jzj.cloudfront.net/582/manual_falconv1.2.pdf.

Ruiz-Sarmiento, Jose-Raul, Samuel-Felipe Baltanas, and Javier Gonzales-Jimenez. 2021. "first_page settings Order Article Reprints Open AccessArticle Jupyter Notebooks in Undergraduate Mobile Robotics Courses: Educational Tool and Case Study." *Applied Sciences* 11 (3): 917. https://doi.org/10.3390/app11030917.

Shibata, Mizuho, Kosei Demura, Shinchi Hirai, and Akihiro Matsumoto. 2021. "Comparative Study of Robotics Curricula." *IEEE Transactions on Education* 64, no. 3 (Aug.): 283-291.

Soto, Alvaro, Pablo Espinace, and Ruben Mitnik. 2006. "A Mobile Robotics Course for Undergraduate Students in Computer Science." *2006 IEEE 3rd Latin American Robotics Symposium*, 187-192. 10.1109/LARS.2006.334322.

Talbert, Robert. 2017. *Flipped Learning: A Guide for Higher Education Faculty*. N.p.: Stylus Publishing, LLC.

Upton, Eben. 2022. "Supply chain update - it's good news!" Raspberry Pi. https://www.raspberrypi.com/news/supply-chain-update-its-good-news/.

Zimmerman, Barry J. 2002. "Becoming a Self-Regulated Learner: An Overview." *Theory Into Practice* 41 (June): 64-70.

Active learning in accessibility: Lessons and challenges from engineering classes in Northern Brazil

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Abstract

This article talks about how active strategies (flipped classes, experience-based learning, and project-based learning) were used in accessibility classes at the Federal University of Pará (UFPA), in Northern Brazil, as part of a civil engineering program. The goal of these courses was to teach about accessibility through design and hands-on experience and to improve "soft skills" like empathy, collaborative thinking, and problem-solving intelligence. Five steps make up the course's method: I) flipped class: students search on their own to learn about accessibility rules and challenges; II) Experience-based learning: a walkout class simulates temporary disabilities in students to improve their empathy for people with disabilities (PWD); III) Experience-reporting and debating: students talk about the walkout and how it changed their lives; IV) Project hands-on: project-based learning took place in designing accessibility interventions for real scenarios; and V) Project presentation: students present their impressions and solutions about issues perceived along the walkout. The most important details are that designing accessible projects requires experience with the daily lives of people with disabilities, being a good citizen, being socially conscious, being emotionally mature, being able to think and work together as a group, and actively learning about accessibility. Higher education institutions and governments should do more to encourage active learning through the challenges they set and the actions they take together. We also suggest that accessibility must extend the theoretical approach by listening to people with disabilities, facing the real problems on site, and putting ourselves in the place of the project user.

Keywords: Flipped class; Experience-based learning; Project-based learning; People with disabilities.

1 Introduction

Engineering has a special place in society, and how engineers design and use interventions has real-world effects. In this role, engineers can solve complex issues, but they must also understand how the social environment impacts their project and construction decisions. Since this is the case, it is very important that engineering education include EDI (equity, diversity, and inclusion) (Pellissier et al., 2022). So, EDI must be considered at every level of engineering design, from small rooms to whole cities, so that everyone, especially people with disabilities (PWD), can access their basic rights, such as human dignity and freedom of movement.

People with disabilities have a hard time getting around in built spaces because buildings aren't made to be accessible. For example, people who have trouble moving around don't have adequate areas of passage, and people who have trouble seeing or hearing don't have visual or auditory signals. In urban areas, these problems also happen when sidewalk slopes are too steep and cars can't be kept away from people walking (Alhusban & Almshaqbeh, 2023). These things get in the way of people with disabilities' right to the city (Lefevbre, 1967) and, by accident, lead to social exclusion. These problems are also caused by the fact that engineering education doesn't teach students how to think about accessibility at all levels of engineering projects (Angrave et al., 2020). Engineering curricula appear to be disconnected from the social role of engineering in society.

The challenge of teaching accessibility is greater in Latin American engineering programs because higher education institutions (HEI) are crawling with social topics in engineering curricula (Neves et al., 2021).

Furthermore, there is less oversight of accessibility laws and standards in buildings and urban areas, which are frequently unsuitable for people with disabilities. So, engineering students have a hard time putting theory and practice together in projects related to accessibility and other social interfaces. In response, the Brazilian Ministry of Education (MEC) put out the National Curriculum Guidelines (*Diretrizes Nacionais Curriculares*, or DCNs) to include social, environmental, and humanities topics in engineering curricula. The DCNs also intend to explore active learning and the development of transversal competences in engineering programs to improve the effectiveness of engineers as society's problem solvers (Carvalho & Tonini, 2017).

Active learning strategies should be a part of engineering curricula so that transversal competences can be fully developed. Flipped classes are a great active method to improve students' motivation for problem solving; it is often their first contact with the subject and improves their confidence to search for the best solution (Christie & De Graaff, 2017). Experience-based learning (EBL), on the other hand, puts students in the middle of the problem and forces them to develop empathy and find hidden problems that can't be seen in theory-based learning (Prince, 2004). Project-based learning (PBL), for example, helps students become more mature by helping them figure out where they are having trouble and how to solve it faster (De Graaff & Kolmos, 1993). So, there is not only one active learning method that improves engineering education separately, but their combination within the didactic plan has greater results and benefits.

Therefore, this study aimed to report the use of active strategies (flipped classes, EBL, and PBL) in accessibility courses offered in a civil engineering program from the Federal University of Pará (UFPA), Northern Brazil. Lessons learned from the application of multiple active strategies are detailed, and challenges to their result in the formation of engineers are discussed. This study adds to the theory of active learning that uses multiple active strategies and the theory of active learning that helps engineering students develop social and transversal competences. We also contribute to the practice of improving accessibility design among engineering students, which certainly will impact Brazilian society soon.

2 Accessibility: From learning citizenship to building opportunities

The Brazilian Association of Technical Standards (ABNT) established Standard NBR 9050/2020, "Accessibility to Buildings, Equipment, and the Urban Environment". This Standard sets principles and technical parameters to be maintained when designing, building, and proceeding with the installation and adjustment of urban buildings to meet the requirements of accessibility. These criteria and technical specifications were based on mobility and perception of the environment, including the use of assistive devices like prostheses, support equipment, wheelchairs, tracking canes, assistive listening systems, and others (ABNT, 2020).

Despite its relevance for the design of buildings and urban spaces, accessibility is not a mandatory topic in engineering curricula in Brazil. Students often develop milestone tasks without including accessibility into their project guidelines. It could be due to a lack of practice in considering accessibility issues in project planning during undergrad, or it could be due to a lack of understanding of regulatory guidelines. Both ways, HEIs and teaching staff contribute to this scenario: Institutions and professors are not well prepared to update their *modus operandi* of teaching engineering (Lima et al., 2022; Neves et al., 2021). Many scholars state that teaching accessibility becomes a challenge because it goes beyond reading technical standards and applying them to software interfaces; it demands soft skills such as empathy, collaborative thinking, and problem-solving intelligence to better design accessible solutions (Angrave et al., 2020; Gall et al., 2013; Martin-Escalona, 2013).

Herein, learning accessibility becomes an exercise in citizenship, especially in cities from developing countries like Brazil. In Northern Brazil, where infrastructure isn't as good and engineering is still struggling to meet social and environmental goals, active learning is shown to be the best way to add lessons on accessibility to undergraduate engineering programs (Lima et al., 2022). Through accessibility courses, engineering students can build spaces that can be used by a wider range of people and come to see their project as part of the whole. It also helps them develop a critical view of local problems, which is important for making cost-benefit analyses to improve local sites and changing their own lives (Mazo, 2010).

3 Methodologies

We report the experience of applying active learning strategies in accessibility classes ministered to civil engineering students of the Federal University of Pará (UFPA), Northern Brazil. These classes are ministered in the course entitled "Legislation and Ethics", a regular curricular component of the civil engineering program. The goal of these courses is to teach humanities to engineering students, which includes accessibility through design and hands-on experience, which helps students see and understand accessibility better in their professional lives. Through this teaching-learning process, we also intend to improve "soft skills" like empathy, the ability to solve problems, and emotional maturity, which are especially important when dealing with EDI. Every semester, this course comprises 40 students per class, ageing from 18 to 30 years-old people.

The course methodology comprises five steps. In step one, students search by themselves to understand accessibility guidelines and challenges. Then, a walkout class simulates disabilities in the students to put them in the place of PWD. The third step consists of debating the walkout experience and how it changed the way students understood accessibility. After that, the students design accessibility projects to solve real problems that had been brought up during the walkout. The fifth and last step is the project presentation to other students, followed by a debate of their found solutions. This study has a qualitative approach and comprises a research strategy of collecting and assessing student and teacher oral reports, as conducted by previous studies (Jackle, 1974; Martin-Escalona et al., 2013). These five steps are detailed as follows:

3.1 Step I: Flipped class

Initially, the professor organizes the student groups and demands research presentations about accessibility topics. The students should read books and articles, watch YouTube videos, interview people with disabilities, and use other strategies to comprehend and present answers to the following questions: What characteristics define a good accessibility project? Are the ABNT accessibility standards followed in local life? Is it should be, then? After the presentations, the students talk about the differences between their groups and try to find arguments that all of them could agree on with the help of the professor.

3.2 Step II: Experience-based learning

After debating and perceiving different views of accessibility, the students walk out of the classroom to a practical activity. The professor puts the students into groups and gives them special tools like wheelchairs, crutches, and blindfolds to make them feel like they have disabilities. Other "angel" students help the "disabled" students and are in charge of directing them along the pathways. During the walkout, "angel" and "disabled" students flip, so everyone can feel both places of accessibility. These walkout activities happen both on the campus of the university and in touristy parts of the Brazilian city of Belém.

3.3 Step III: Experience-reporting and debating

After the walkouts, the students return to the classroom and debate the experience. Is disability a struggle to assure the right to mobility? or even human dignity? Are local buildings and urban spaces prepared for PWD? Are Brazilian standards for accessibility correctly applied in engineering projects? Why not? Should designers put themselves in PWDs' place to improve their projects? Again, different perceptions are put on the table, and common arguments try to be stated.

3.4 Step IV: Project hands-on

After realizing how accessibility works in practice and how engineering design can embrace it, students design accessibility interventions for the places where the walkouts occur to solve their real problems. They come back to the places to measure, register issues, and talk to real PWD who use these areas to better design effective interventions. During the project, students employ the Brazilian standard NBR 9050 and point out its flaws in order to achieve real accessibility excellence.

3.5 Step V: Project presentation

Finally, the groups present their projects in final presentations. Solutions and propositions are debated among other groups, creating a more collaborative environment for accessibility design. Professional designers help the professor guide the students as they work to solve problems, which makes the students feel more connected to the local workforce. The students also debate how they changed along the course regarding the development of soft skills. They state that the experience becomes a turning point in their lives, improving their empathy, maturity, and self-confidence in solving social problems.

4 Results and Discussion

Accessibility is not an elective topic in the formation of engineering students, or it shouldn't be. So, we'll start by talking about what we've learned from teaching and learning about accessibility in an engineering program where this topic hasn't always been part of the curriculum. After that, we talk about the problems we ran into while making the engineering curriculum more accessible and how it can be used in other programs around the world.

4.1 Lessons from active learning in accessibility

Most of the walkouts occur on the UFPA campus (Figure 1). Each student group roams a different pathway and meets at the end of an hour. Some students cannot play the visual disability; they cry. Walking around a usual pathway (the university campus) is completely different without vision for most students, and they cannot access habitual places without the angel students. Students with wheelchairs or crutches argue that they have a great deal of difficulty navigating sidewalks, obstacles, and even other students who don’t care about their temporary disability. These students figure out that a minimum slope that is different from what is recommended can directly affect the ability of locomotor PWD to move around on their own.

The perception of inaccessibility is everywhere on and outside the university campus: lack of proper illumination in pathways; street signals that don’t guide pedestrians or car drivers to respect PWD displacements; water fountains and bathrooms that aren’t made for PWD users. The students feel for themselves how cruel inaccessibility can be. Even the angel students notice subtle things about accessibility that are hard to predict if you don't know how people with disabilities move around. For example, the steeper stairs make it harder to move around, the sinks and trash cans aren't made well, and there are no braille signs. The students can then understand the living accessibility; through empathy, they can see how projects can mitigate such struggles and improve the dignity of several users of their projects.

However, not only bad aspects are noticed in the walkouts: students realize that other unknown students help them move around. There is kindness and empathy to take them on and off the university bus, to help them enter the restaurant, and to guide them across crosswalks. Real PWD students who meet on the walkouts share their experience with the students: people mostly help them, but accessibility must exist beyond kindness; it has to allow people with disabilities to live their lives independently, with dignity and respect. Therefore, at the conclusion of the EBL, students can list some lessons after presentations:

- Designing accessibility projects demands experience in PWD routines to perceive hidden struggles that most of engineers cannot predict by only reading the technical standards;
- Designing accessibility is exercising citizenship. It engages engineers to socially participate of debates, regulatory laws, and city interventions who can impact direct and indirectly PWD, and not restricting their actuation to the technical design and construction;
- Designing accessibility represents social conscientiousness. It deprehends the engineers are fully empathic with PWD difficulties and work hard to mitigate minimum hampers to PWD daily life. It demands also emotional maturity, collective thinking and work-together abilities, somethings that engineering schools are not prepared to develop in their students;
- Accessibility should be actively learned, that be, the students should explore the world they want to change. Only by feeling the struggles and touching real problems they can effectively see the answers and properly intervene.

These students and teachers' perceptions are similar to other experiences with accessibility worldwide. In Japan, despite there are students struggling to understand PWD needs in university, HEIs are starting to establish formal courses to promote accessibility guidelines in different majors (from medicine to engineering), what sooner can represent effect changes in Japanese society (Iwakuma et al., 2023). When playing disability simulation (DS), which has been used as an experiential learning tool for health science students (Jackle, 1974; Kilbane, 2000; Nario-Redmond et al., 2017), engineering students improve their skills of assessing technical issues derived from the PWD perceptions, what then improve the accessibility design (Van Puymbrouck et al., 2017).

Figure 1. Walkout experience

4.2 Challenges in teaching and learning accessibility

Teaching and learning accessibility is not an easy goal to reach because it requires joint actions from multiple educational actors: governments, institutions, professors, and students. Even though there are standards and technical-legal regulations, governments and universities don't teach about accessibility as much as they should. The reason for that comes from multiple sides: professors who don't want to update their didactic strategies, a lack of institutional determination to add accessibility to the curriculum, a lack of practical touch in PWD reality in curricular projects, or an insufficient touch with social topics in classes. Passive learning techniques, which demotivate students to understand what and why they are learning such topics, are a part of all those struggles. By using these passive methods, learning accessibility becomes a reading standards lesson and a design software exercise. There is no attachment to real life or to real people. No standard can predict every struggle a PWD could experience.

In this sense, students need motivation and the real meaning of their role in people's lives. Academia can do this by giving students hands-on lessons and experiences that show them other ways of life and help them develop soft skills like empathy, emotional intelligence, and the maturity to understand different people and their needs. It makes engineers more socially aware and involved, and it also makes them better prepared for the job market by making them work in teams and respecting and promoting EDI. To address such remarks, we need transversal interventions: governments must encourage active learning in higher education institutions more effectively, and institutions must apply active teaching and learning fundamentals in their curricula. It requires that professors change the way they teach and that students try new ways to learn.

5 Conclusion

We reported the use of active strategies in accessibility courses offered in a civil engineering program from the Federal University of Pará (UFPA), Northern Brazil. By using multiple active strategies (flipped classes, experience-, and project-based learning), the students could understand accessibility in real life and then design more effective accessibility projects. We have learned from these classes that accessibility must extend the theoretical approach by listening to people with disabilities, facing the real problems on site, and putting ourselves in the place of the project user. Therefore, we develop soft skills to improve our technical execution and professional guidance. The problems of figuring out how to teach and learn about accessibility go beyond professors and students. They should also involve the actions of governments and institutions as a whole, so that the right experience can change the way technical designers work. We added to the theory of active learning, which uses multiple active strategies and helps engineering students learn social and cross-disciplinary skills. We also contribute to the practice of improving accessibility design among engineering students, which certainly will impact Brazilian society soon.

6 References

Alhusban, A. A., & Almshaqbeh, S. N. (2023). Delivering an inclusive built environment for physically disabled people in public universities (Jordan as a case study). Journal of engineering, design, and technology. https://doi.org/10.1108/JEDT-06-2022-0281

Angrave, L., Jensen, K., Zhang, Z., Mahipal, C., Mussulman, D., Schmitz, C. D., Baird, R. T., Liu, H., Sui, R., Wu, M. S., & Kooper, R. (2020). Improving Student accessibility, Equity, Course performance, and Lab skills: How introduction of class transcribe is changing engineering education at the University of Illinois. American Society of Engineering Education Virtual Conference, June 22-26 2020. 29904. Available at: https://eric.ed.gov/?id=ED610559

Brazilian Association of Technical Standards. 2020. NBR 9050 "Accessibility to Buildings, Equipment, and the Urban Environment". Rio de Janeiro: ABNT.

Carvalho, L. A. & Tonini, A. M. (2017). A comparative analysis of the competences required in contemporary professional practice of engineers and those in the national curriculum guidelines for engineering courses. Gest. Prod., 24, 4, p. 829-841. http://dx.doi.org/10.1590/0104-530X1665-16

Christie, M. & De Graaff, E. (2017). The philosophical and pedagogical underpinnings of Active Learning in Engineering Education. Eur. J. Eng. Educ. 42, 5–16

De Graaff, E. & Kolmos, A. (1993). Characteristics of Problem–Based Learning. Int. J. Eng. Educ., 19, 657–662

Gall, K., Knight, D. W., Carlson, L. E., & Sullivan, J. F. (2013). Making the Grade with Students: The Case of Accessibility. Journal of Engineering Education, 92(4), p. 337–343. https://doi.org/10.1002/j.2168-9830.2003.tb00778.x

Iwakuma, M., Miyamoto, K., & Murata, J. (2023). Changes in Perceptions of Japanese University Students toward Disability: A Mixed Methods Study. Int J Disability, Development and Education, 70(2), p. 156-168. https://doi.org/10.1080/1034912X.2020.1865521

Jackle, M. J. (1974). Experiential learning in rehabilitation. The Journal of Continuing Education in Nursing, 5(6), 19-21. https://doi.org/10.3928/0022-0124-1974110108

Kilbane, J. (2000). The other shoe: A disability du jour learning strategy. AOTA Education Special Interest Section Quarterly, 10, 3-4

Lefevbre, H. (1967). The right to the city. In: KOFMAN, E.; LEBAS, E. (Ed.). Writings on Cities London: Blackwell, 1967. p. 63-184.

Lima, G.V.B.A., Carvalho, A.C., & Neves, R.M. (2022). Influence of institutional factors on the civil engineering student performance in Brazil. European Journal of Engineering Education 47(6), 1179-1196. https://doi.org/10.1080/03043797.2022.2134759

Martin-Escalona, I., Barcelo-Arroyo, F., & Zoa, E. (2013). The introduction of a topic on accessibility in several engineering degrees. 2013 IEEE Global Engineering Education Conference (EDUCON), Berlin, Germany, 2013, pp. 656-663, doi: 10.1109/EduCon.2013.6530177.

Mazo, R. (2010). Ensino de arquitetura e concepção de professores sobre acessibilidade, inclusão social, desenvolvimento humano e deficiência. Dissertation thesis (Masters in Psychology), Universidade Estadual Paulista, Faculty of Sciences, Available in: http://hdl.handle.net/11449/97487.

Nario-Redmond, M. R., Gospodinov, D., & Cobb, A. (2017). Crip for a day: The unintended negative consequences of disability simulations. Rehabilitation Psychology (Epub), 62(3), 324-333. https://doi.org/10.1037/rep0000127

Neves, R.M., Lima, R.M., & Mesquita, D. (2021). Teacher Competences for Active Learning in Engineering Education. Sustainability 13, 9231. https://doi.org/10.3390/su13169231

Pellissier, R., Siluk, F., Flynn, C., & Kanaan, M. (2022). Approaching equity, diversity, inclusion, and social justice education as imperative to engineering curricula. Proceedings 2022 Canadian Engineering Education Association (CEEA-ACEG2022) Conference.https://doi.org/10.24908/pceea.vi.15924

Prince, M. (2004). Does Active Learning Work? A Review of the Research. J. Eng. Educ. 93, 223–231.

VanPuymbrouck, L., Heffron, J. L., Sheth, A. J., The, K. J., & Lee, D. (2017). Experiential Learning: Critical Analysis of Standardized Patient and Disability Simulation. Journal of Occupational Therapy Education, 1(3). Retrieved from https://encompass.eku.edu/jote/ vol1/iss3/5

Investigating Engineering Contributions in Hackathons: Metaverse and Blockchain as Key Components for E-commerce

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Abstract

This research aims to examine the efficacy of hackathons as educational instruments for engineering students at Mackenzie University, focusing on creating innovative metaverse logistics solutions using blockchain technology. These events have gained popularity and provide a unique platform for students and professionals to demonstrate their abilities, creativity, and problem-solving skills. The investigation adopts a case study methodology to analyze the qualitative and descriptive statistical data gathered during the hackathon event. The hackathon at University Presbyterian Mackenzie is a cooperative event where students, professors, and 11 companies collaborate to devise innovative solutions for complex challenges. The Grupo Petrópolis company posed a metaverse innovation challenge to the engineering school. The study's findings emphasize the challenges encountered by the blockchain-related metaverse, currently involved in establishing the infrastructure for IoT devices, integrated systems, data security, and internet speed. Consequently, the research suggests that the TIMTIM group's project has not yet demonstrated a robust link between the technological design of the metaverse and e-commerce practices.

Keywords: Hackathon; Metaverse; Engineering Education; Reverse Logistics.

1 Introduction

The metaverse, a digital evolution chapter, has the potential to transform various industries through its four foundational pillars: ubiquitous connections, space convergence, virtuality, and reality interaction, and human-centered communication (Egliston & Carter, 2022; Huynh-The et al., 2023; Shi et al., 2023). Lee et al. (2021) offer a framework for understanding the metaverse: lifelogging, shared space in virtuality, internet/spatial internet, mirror world, and an omniverse - a place for simulation/collaboration, which has gathered investments from Meta Platforms Inc. (Facebook), Epic Games, and Microsoft. The metaverse's potential impact embraces several sectors, including gaming, education, media, entertainment, e-commerce, manufacturing, architecture, and engineering (Huynh-The et al., 2023). Thus, Lee et al. (2021) and Huynh-The et al. (2023) studies linked blockchain technology with the metaverse in order to achieve enhanced security, decentralization, and payment flow. A blockchain is a decentralized digital database that stores records of all transactions or events executed and shared among participants (Crosby et al., 2016). It is a public ledger that is verified by the consensus of the majority of the participants in the network, where each transaction is permanently recorded and cannot be altered or deleted (Ahmed et al., 2022; Crosby et al., 2016). The immutability and transparency of the blockchain ensure a particular and verifiable record of every transaction ever made (Ahmed et al., 2022; Crosby et al., 2016). Blockchain has the potential to create transparency by enabling all members of the network to access the same data, providing a single source of truth (Hackius & Petersen, 2017). For instance, Brazilian companies Beenoculus and Sthorm have contributed to the metaverse's growth in Brazil through virtual reality (VR), augmented reality (AR), and mixed reality (MR) technologies, along with blockchain technology. They have participated in the United Nations (UN) assembly and pushed the boundaries of digital experiences, paving the way for the metaverse, NFTs, and blockchain. However, the metaverse's full potential and practical uses seem to be intangible or elusive (Egliston & Carter, 2022; Shi et al., 2023). It means that metaverse and blockchain technology need more studies and collaboration among academia, industry, and tech experts. Huynh et al. (2023) uphold that the metaverse ecosystem relies on blockchain technology for content and transaction management. Blockchain's decentralized ledger content and cryptographic measures ensure secure sharing and digital asset tracking (Biggs et al., 2022; Gökalp et al., 2022). In the metaverse context, blockchain enforces accountability within the digital ecosystem, making it more secure and suitable for e-commerce platforms. In this way, Grupo Petrópolis (GP) has introduced the idea of combining the metaverse with reverse logistics. Through a hackathon event at University Presbyterian Mackenzie, the company GP challenged engineering students to create a metaverse that promotes reverse logistics awareness in 2022. This research aims to investigate the potential of hackathon events as educational tools for fostering innovation among Brazilian engineering students in the metaverse/blockchain technology context. Adopting a qualitative research approach, the study employs a case study methodology to analyze data collected during the hackathon event. The research question raised: how do hackathons effectively engage engineering students in developing innovative metaverse logistics solutions leveraging blockchain technology? The following sections will present a comprehensive literature review covering hackathons, collaborative learning, team problem-solving, metaverse, and blockchain. The research methodology, case study, data analysis, and conclusions drawn from this study will also be discussed.

2 Hackathon Events: Promoting Collaborative Learning and Team Problem-Solving

Hackathons, originating in 1999, are collaborative events where professionals develop new technological solutions or software applications. Initially organized by technology corporations, hackathons gained popularity and were adopted by universities and organizations globally (Garud et al., 2002; Rys, 2021). One of the largest university hackathons is the Major League Hacking's (MLH) Local Hack Day, with MLH supporting and organizing hackathons primarily at universities across North America, Europe, and Asia. Annually, MLH brings together around 65,000 participants and hosts 200 hackathons from various universities and colleges worldwide, showcasing the potential of hackathon outcomes for collaborative engagement (Angarita & Nolte, 2020). This collaborative engagement is what Angarita & Nolte (2020) discussed as the potential of the hackathon's outcomes:

Tangible outcomes	**Synthesis**
Technical artifacts	New prototypes, product features, bug fixes
Non-technical artifacts	Visualizations, new or improved documentation, publication
Intangible outcomes	**Synthesis**
Learning	New technologies, acquiring industry and university skills
Networking	Team builds, meetings, meeting new people, creating opportunities for collaboration
Interdisciplinary	Multiple disciplines and professors mentoring, cross-disciplinary collaboration
Ideas	Creativity environment for a new perspective
Entrepreneurship	Recognize opportunities, develop innovative ideas, and take steps to turn these ideas into viable businesses.
Fostering enterprise	Identifying a problem or opportunity in the market and developing a unique solution or product to address it.
Fostering awareness	By showcasing the innovative solutions developed during hackathons, the events can raise public awareness about the potential applications

The framework for the outcomes appears to enhance the elements involved in the scale-making impact of hackathon events (Angarita & Nolte, 2020; Schaedler et al., 2022). These can be broadly categorized into tangible and intangible outcomes. Tangible outcomes primarily consist of technical and non-technical artifacts. Technical artifacts include the creation of new prototypes, the development of product features, and the fixing of software bugs. These contribute to the practical applications of the solutions devised during the hackathon and signify the technological advancements made through the event. Non-technical artifacts, on the other hand, involve the production of visualizations, the generation of new or improved documentation, and the publication of findings. These elements amplify the knowledge sharing and dissemination aspects of the hackathon, making it easier for the broader community to understand and build upon the work carried out. Furthermore, cooperative learning involves students of varying abilities engaging in dialogue, addressing challenges, and collaborating in small teams to achieve a shared objective (Horton et al., 2018; Mehta et al., 2022; Porras et al., 2018). This pedagogical approach improves the practice and analytical reasoning abilities (Kvamsås et al., 2021; Steglich et al., 2021). Laal & Ghodsi (2012) identified four benefits of collaborative learning: social, psychological, academic, and evaluation related. As a result, educators have designed cooperative learning activities such as hackathons, coding camps, and development camps to foster modern learning competencies and promote collective innovation.

2.1 Building Trust in the Metaverse: Leveraging Blockchain Technology for Authentic Data in Social Networking Platforms

Metaverse is an emerging concept that describes a virtual world parallel to our physical world. Figure 1 shows the technical elements.

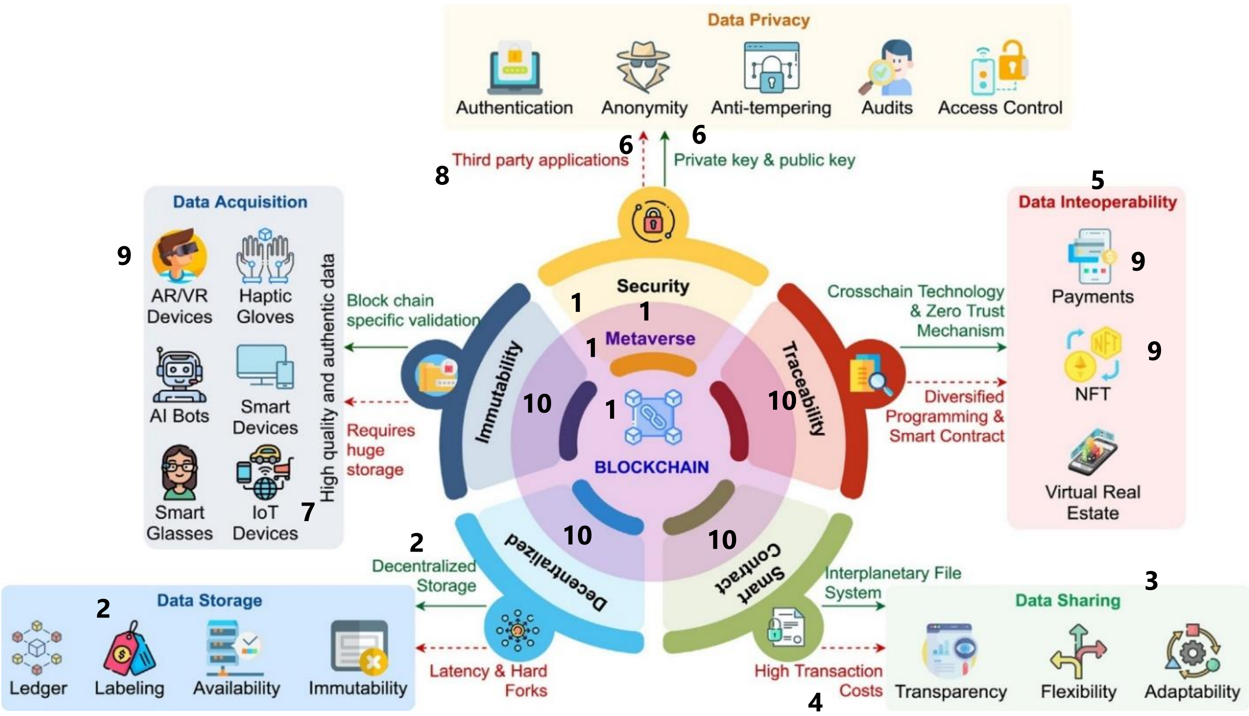

Figure 1: Framework adapted by Huynh-The et al. (2023 p. 407) about the blockchain for technical aspects in the metaverse:

Huynh-The et al. (2023) suggest that blockchain technology can be applied to the metaverse to address various infrastructure and systems integration barriers (1). Simply put, the metaverse faces difficulties in collecting high-quality and genuine data. Blockchain offers a solution, but its complexity and decentralized nature may result in slower transactions and increased storage requirements (2). Therefore, companies and researchers have been working to create more advanced blockchain applications for the metaverse. Blockchain's decentralized structure speeds up identifying and labeling data (2), making it a valuable tool for data scientists. It also ensures data reliability, transparency, and accessibility within the metaverse (3). Using blockchain technology can enhance the adaptability and flexibility of data in the metaverse (3).

Nonetheless, with more metaverse users comes the need for more computing resources and higher transaction costs (4). Therefore, future-generation blockchains should address these challenges to enable efficient data sharing (3). Another issue is the lack of interoperability between virtual worlds (5). Different public blockchains in various virtual worlds lack a shared language, payments, and NFTs, making cross-blockchain-enabled metaverse interoperability difficult (5). Blockchain can help maintain privacy in the metaverse, but human errors like losing private keys can weaken security (6). Besides, attackers may target third-party applications with weak security mechanisms (6), leading to compromised personal information. Blockchain can also support the secure sharing and storage of accurate data from IoT devices across multiple virtual worlds (7). Despite this, there are still challenges to address, such as verifying non-public IoT data (7), tracing IoT transactions (7) involving illegal services, and identifying responsible parties for specific behaviors. Integrating blockchain technology with digital pairs (8) can efficiently manage data, addressing trust, integrity, and safety concerns (8). Standardization, privacy, and scalability issues must be resolved to implement digital twin applications in the metaverse successfully. Merging AI and blockchain can protect sensitive data needed by AI-driven systems. However, the openness of public blockchains could harm AI models in the metaverse, and attackers might exploit AI vulnerabilities without proper regulations. Therefore, cross-chain converters are crucial, enabling AI applications to work with different blockchains. Blockchain technology has significant potential for big data analytics in the metaverse, allowing users to retain control over their personal information and financial activities. However, challenges such as consensus models, mining costs, and transaction verification still need to be addressed. In addition, blockchain integration with the metaverse is still in its early stages, but overcoming these challenges will unlock new opportunities. Lastly, multi-sensory XR applications (9), holographic telepresence (9), and blockchain technology (9) can merge digital economies into unified platforms for managing assets and payments (9) in the metaverse (the e-commerce at Grupo Petrópolis). However, emerging blockchain platforms must address concerns like deep AI fakes (10). IoT devices, digital pairs (10), and XR applications (10) will generate big data in the metaverse, and blockchain will help secure and manage (10) this data. Blockchain's impact on the technical aspects and various enabling technologies of the metaverse is significant and will continue to shape its development (Egliston & Carter, 2022; Huynh-The et al., 2023).

3 Method

In this study, we propose to discuss how hackathons engage engineering students in developing innovative Metaverse logistics solutions, leveraging blockchain technology. In doing so, we chose a qualitative research approach applying a case study to explore the hackathon data at the University Presbyterian Mackenzie.

3.1 Methods that pathway analysis

This research opted to a case study methodology to investigate the hackathon event at Mackenzie University and its role in promoting innovative Metaverse logistics solutions among engineering students. The case study approach allows for an in-depth examination of the specific context and dynamics of the hackathon event while considering its broader educational implications. Data collection was carried out through a participant observation technic. Participant observation was employed during the hackathon event for five days. The technic helped to gather insights into the interactions, collaborations, and learning processes of the students. Detailed field notes were taken to record observations and document the students' experiences. In addition, there were open-ended questions interviews made with TIMTIM group – 6 students (Hackathons winner), two faculties' members, and three representatives from the collaborating company – Grupo Petrópolis. The interviews explored participants' perspectives on the hackathon's educational value, the student's learning experiences, and the potential for innovative Metaverse logistics solutions. We have applied the open-ended questions and allowed participants to share their thoughts and experiences in their own words, providing a rich understanding of the event's impact. The data analysis involved content analysis throughout categories: tangible outcomes and intangible outcomes.

Additionally, the subcategories were: technical artifacts, non-technical artifacts, learning, networking, interdisciplinary, ideas, entrepreneurship, fostering existing enterprise, and fostering awareness about hackathon themes. The hackathons' data supports the analysis to roadmap tangibles and intangibles outcomes that contributed to the student's learning experience and fostered innovation in Metaverse logistics. Table 1 summarizes the numbers of companies, sort of industry, problem statement, the spectrum of the hackathon along with engineering at the University Presbyterian Mackenzie, and the number of teams in 2022:

Table 1: hackathons' Statistics 2022

	Industry	Company	Hackathon problem statement	Civil	Electrical	Materials	Mechanics	Production	Chemical	Computing Technology
Economy sector: secondary	Base industry	Abinox	Stainless steel	8	1	24	21	17	1	0
	Base industry	Antares Reciclagem	Removal of metals in acid medium	1	1	2	3	5	36	0
	Industrial automation and technology	Festo	Bionix robots in solving industrial problems	11	59	3	46	2	0	2
	Beverage industry	Grupo Petrópolis	Creation of a virtual universe, metaverse with innovation and sustainability	45	17	5	32	121	0	1
	Construction	Mega Reforça	Execution of foundations in unusual works	46	0	0	0	3	0	0
Economy sector: tertiary	Base industry	Ericsson	5G Solutions in Smart Cities	19	36	1	14	29	0	0
	Consulting and auditing	Ernst & Young	Problem-solving in supply chain management	26	18	6	26	258	0	0
	Industrial waterproofing	Georevest	Solutions for installing prefabricated coatings for waterproofing water supply tanks and sewage collection networks	22	0	0	2	0	0	0
	Financial services	Itaú	Itaú Mackenzie Data battle	8	10	6	10	8	2	9
	Real estate and construction Base industry Base industry	Tegra1	Improvement of the execution of baldrame beams in structural masonry projects	71	1	1	3	4	0	0
		Tegra2	Energy: monitoring, consumption, and alternative sources	27	23	1	3	16	0	0
		Tegra3	Innovation in façade solutions	99	0	0	0	6	0	0
	Industrial automation and technology	TPF Engenharia	Decision-making for criteria for choosing a railroad route	83	7	0	50	37	0	0
	Nº teams: 349		Total of students: 1455	466	173	49	210	506	39	12

4 Grupo Petrópolis Data Analysis Challenge: Metaverse, reverse logistics and blockchain technology: Unveiling Insights and Innovations

Figure 2 describes the victorious student team at the hackathon. Their success can be attributed not only to their skills and dedication but also to the supportive infrastructure provided by the event. It seems that the environment fosters collaborative interactions, enabling students to work together and learn from one another effectively.

Mackenzie University has strategically designed spaces and classrooms that promote collaboration and creativity among students, faculties, professors, coordinators, and members of industries during the hackathon. These areas include state-of-the-art meeting rooms, conference facilities, and technology-equipped workspaces: TV screens, monitors, laptops, and data-show that facilitate seamless communication and knowledge exchange.

Figure 2: Team winner of the Grupo Petrópolis challenger and classroom structure. Photo by Dado Nogueira in Hackathon 2022 at the University Presbyterian Mackenzie

In order to inspire and motivate students throughout the challenge, Grupo Petrópolis offered prizes to the top three teams. In addition, the victorious team was granted a one-of-a-kind opportunity to participate in the meeting to further implement their project, named "E-commerce," a solution integrating metaverse, reverse logistics, and blockchain technology. Figure 3 shows a part of Timtim team, accompanied by their mentoring professors and company member visiting Grupo Petropolis's headquarters in Boituva-SP:

Figure 3: shows a part of Timtim team

Table 2 shows what Timtim team has proposed to design the e-commerce project:

Tangible outcomes	Ideas of the project I - TIMTIM
Technical artifacts	App to attract customers to collect SKINs (unique and rare rewards on products sold by), QR code on Grupo Petrópolis product packaging to redeem points or rewards, Machines at Ecopoints with barcode reading on the packaging, Transfer of NFTs from Grupo Petrópolis for customers, Cash-back System to retain customers
Non-technical artifacts	Petrópolis Group customers can return recyclable packaging to redeem points and earn SKINs at Ecopoints, SKIN Rarity Degree

Intangible outcomes	Ideas of the project II - TIMTIM
Learning	Adequacy of the project for e-commerce and for Grupo Petrópolis points of sale
Networking	Company directors, managers, and analysts in rounds of meetings in Boituva
Interdisciplinary	Production, Mechanical and Electrical Engineering
Ideas	Integrate the metaverse with reverse logistics and blockchain
Entrepreneurship	Intrapreneurship applied in the context of the company.
Fostering existing enterprise	New technology for transferring NFTs from a company to an individual
Fostering awareness about hackathon theme	Engagement of students during monitoring meetings with professors and company professionals.

The TIMTIM team has suggested an innovative e-commerce project for Grupo Petrópolis that includes an App for attracting customers through unique and rare product SKIN rewards. The project involves QR codes on product packaging to redeem points or rewards, machines at the Ecopoints with barcode reading capabilities for packaging, NFT transfers from Grupo Petrópolis to customers (Blockchain technology in e-commerce), and a cash-back system for customer retention. In doing so, the project proposed that customers might return recyclable packaging to Ecopoints. It is encouraged to redeem points and earn SKINs with varying degrees of rarity. The project was designed for both e-commerce and Grupo Petrópolis points of sale. Company directors, managers, and analysts participated in some rounds of meetings in Boituva – Sao Paulo and online, collaborating with students from production, mechanical, and electrical engineering disciplines. The LIS - Innovation and Sustainability Lab by Grupo Petrópolis was a significant project. The LIS team has guided TIMTIM team for a culture of open innovation and sustainability ecosystem on processes, products, and services. Grupo Petrópolis has implemented LIS to encourage professionals and society to generate ideas, connecting the organization with intelligent and sustainable solutions aligned with the company's strategy.

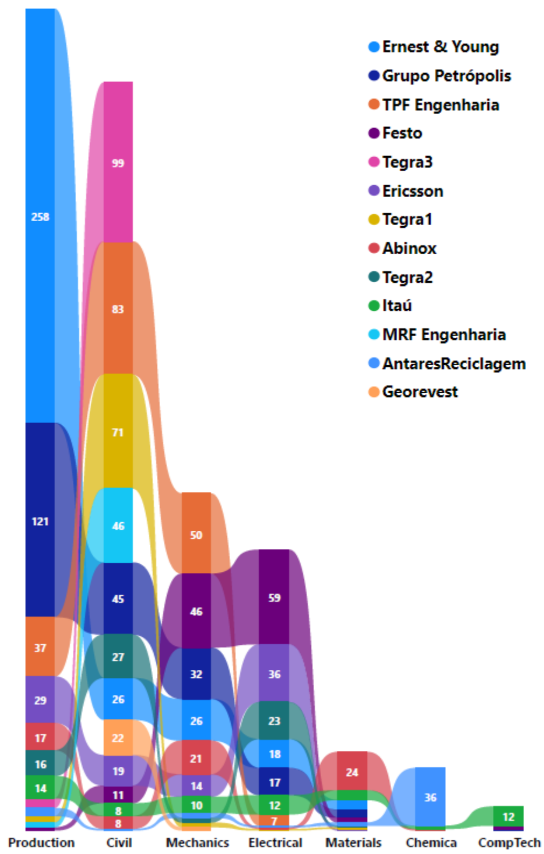

Figure 4 indicates the engineering students' distribution of all challenges statements on the hackathon. The hackathon presented different companies, encouraging students to develop innovative solutions in a wide range of fields: Ernst & Young Challenge, Grupo Petrópolis Challenge - Creation of a virtual universe (metaverse) linked to innovation and sustainability awareness, TPF Engenharia Challenge, Festo Challenge, Tegra3, Ericsson, Tegra1, Abinox, Tegra2, Itaú, MRF, Antares Reciclagem, and Georevest. Engineering of Production, Civil, Mechanics, Electrical, Chemical, and Computing and Technology have partaken with 349 teams and 1455 total of students.

A student from Production Engineering said: [...] *hackathon was a game-changer for me. It not only helped me to sharpen my problem-solving and teamwork skills but also exposed me to the latest technologies and trends in the industry*.

Another Mechanics student affirmed: [...] *challenges presented by the companies were thought-provoking and stimulate out-of-the-box thinking. I believe the hackathon has prepared me better for my future career, and I am grateful for the opportunity*.

Finally, the Civil student says: [...] *participating hackathon was an incredible experience. It allowed us to think creatively and collaborate with fellow students from different courses. It was all new. Overall, the hackathon was a rewarding and enriching learning experience.*

5 Conclusion

In 2022, the School of Engineering at Mackenzie Presbyterian University and 11 companies achieved significant results through collaborative learning during the hackathon. Notably, Grupo Petrópolis exposed engineering students to the metaverse, reverse logistics, and blockchain challenges. The winning TIMTIM team presented their project at Grupo Petrópolis headquarters, receiving support for their careers and further projects related to the innovation lab of sustainability (LIS) of Grupo Petrópolis. At first, the examination of blockchain technology for the metaverse revealed the substantial potential to transform immersive experiences across various applications and services in logistics and e-commerce. Nevertheless, critical challenges persist, including data latency, security, technology scalability, and decentralization. Given the significance of the topic, it becomes crucial to continue the development of innovative strategies aimed at enhancing the infrastructure, Internet of Things (IoT) devices, high-speed internet services, and the effective integration of systems. Furthermore, the issue of high energy consumption and the consequent greenhouse gas emissions from networks emerge as global scale concerns, requiring immediate attention and solutions. Thus, it becomes clear that there is a need for further research to understand in depth the implications and benefits that hackathons can bring by stimulating the creation of innovative logistics solutions for the metaverse. Future studies should consider investigating the scalability and adaptability of the proposed solutions, as well as explore the broader ramifications of the implementation of metaverse technologies, reverse logistics, and blockchain across different sectors.

6 References

Ahmed, W. A. H., MacCarthy, B. L., & Treiblmaier, H. (2022). Why, where, and how are organizations using blockchain in their supply chains? Motivations, application areas, and contingency factors. *International Journal of Operations and Production Management*, *42*(12), 1995–2028. https://doi.org/10.1108/IJOPM-12-2021-0805

Angarita, M. A. M., & Nolte, A. (2020). What do we know about hackathon outcomes and how to support them? – A systematic literature review. *Springer Nature Switzerland*, *123*(24), 50–64. https://doi.org/10.1007/978-3-030-58157-2_4

Biggs, J., Hinish, S. R., Natale, M. A., & Patronick, M. (2022). Blockchain: Revolutionizing the Global Supply Chain by Building Trust and Transparency. *Operations Analysis*.

Crosby, M., Nachiappan, Pattanayak, P., Verma, S., & Kalyanaraman, V. (2016). Blockchain Technology: Beyond Bitcoin. *Applied Innovation Review*, *2*(1), 1–16.

Egliston, B., & Carter, M. (2022). 'The metaverse and how we'll build it': The political economy of Meta's Reality Labs. *New Media and Society*. https://doi.org/10.1177/14614448221119785

Garud, R., Jain, S., & Kumaraswamy, A. (2002). Institutional entrepreneurship in the sponsorship of common technological standards: The case of sun Microsystems and Java. *Academy of Management Journal*, *45*(1), 196–214.

Gökalp, E., Gökalp, M. O., & Çoban, S. (2022). Blockchain-Based Supply Chain Management: Understanding the Determinants of Adoption in the Context of Organizations. *Information Systems Management*, *39*(2), 100–121. https://doi.org/10.1080/10580530.2020.1812014

Hackius, N., & Petersen, M. (2017). Blockchain in Logistics and Supply Chain: Trick or Treat? *Hamburg International Conference of Logistics HICL*, 1–16.

Huynh-The, T., Gadekallu, T. R., Wang, W., Yenduri, G., Ranaweera, P., Pham, Q. V., da Costa, D. B., & Liyanage, M. (2023). Blockchain for the metaverse: A Review. *Future Generation Computer Systems*, *143*, 401–419. https://doi.org/10.1016/j.future.2023.02.008

Kvamsås, H., Neby, S., Haarstad, H., Stiller-Reeve, M., & Schrage, J. (2021). Using collaborative hackathons to coproduce knowledge on local climate adaptation governance. *Current Research in Environmental Sustainability*, *3*. https://doi.org/10.1016/j.crsust.2020.100023

Laal, M., & Ghodsi, S. M. (2012). Benefits of collaborative learning. *Procedia - Social and Behavioral Sciences*, *31*, 486–490. https://doi.org/10.1016/j.sbspro.2011.12.091

Lee, L.-H., Braud, T., Zhou, P., Wang, L., Xu, D., Lin, Z., Kumar, A., Bermejo, C., & Hui, P. (2021). All One Needs to Know about Metaverse: A Complete Survey on Technological Singularity, Virtual Ecosystem, and Research Agenda. *Journal of LATEX Class Files*, *14*(8), 1–66. http://arxiv.org/abs/2110.05352

Rys, M. (2021). Invention Development. The Hackathon Method. *Knowledge Management Research and Practice*, *24*(4), 1–14. https://doi.org/10.1080/14778238.2021.1911607

Schaedler, C., Wegner, D., & Brambilla, F. R. (2022). Hackathons como estratégia para inovação aberta: insights de eventos no Brasil e no Canadá. *Revista de Administração Da UFSM*, *15*(4), 563–580. https://doi.org/10.5902/1983465969319

Shi, F., Ning, H., Zhang, X., Li, R., Tian, Q., Zhang, S., Zheng, Y., Guo, Y., & Daneshmand, M. (2023). A new technology perspective of the Metaverse: Its essence, framework and challenges. *Digital Communications and Networks*. https://doi.org/10.1016/j.dcan.2023.02.017

Steglich, C., Marczak, S., Guerra, L., Trindade, C., Dutra, A., & Bacelo, A. (2021). An Online Educational Hackathon to Foster Professional Skills and Intense Collaboration on Software Engineering Students. *ACM International Conference Proceeding Series*, 388–397. https://doi.org/10.1145/3474624.3476973

Active Methodology and Digital MKT: experience report on the construction and application of the game in the classroom

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Abstract

The work described the construction process of a serious game applied in a marketing class in higher education in Brazil Digital marketing has been increasingly demanded by the market and has undergone many innovations in recent years, requiring that updates of techniques and tools are quick and frequent in the classroom. Thus, the study is characterized as Design Science and uses reasoning, development and evaluation techniques for the development of the serious game MKT Digital. Serious games, as an active methodology, help in cognitive development based on ludic dynamics and reward systems and techniques. The results demonstrate good adherence by the students, as well as good performance with regard to marketing practices in the digital context.

Keywords: Active Learning; Gamification; Marketing.

1 Introduction

Education has been undergoing significant changes from the technological development of the last 20 years, changing the school space and pedagogical practices, traditionally banking, to a more interactive and entrepreneurial perspective. In this context of mass use of Digital Technologies and cyberculture, resources that stimulate learning are adopted (Kapp, 2012).

One of these resources are games, used as a playful and active method of cognitive development for children, youth and adults (Dominguez et al, 2013) in formal education. Thus, gamification as an active methodology based on the use of digital game elements in the classroom encourages student engagement through rewards. Gamification or a gamified environment requires systems, mechanics, aesthetics and game thinking in contexts external to the games themselves (Kapp, 2012; Vianna et al 2013; Plass, Homer, & Kinzer, 2015). "However, the educational domain has been somewhat riddled with conceptual unclarity as the terms of gamification, game-based learning and serious games are all commonly used to refer to the use of games in education contexts" (Plass, Homer, & Kinzer, 2015, p. 197), thus, the conceptual differences will not be detailed in this work.

In this sense, digital transformation "has fundamentally altered consumers' expectations and behaviors, pressured traditional firms, and disrupted numerous markets" (Verhoef, Broekhuizen, Bart, Bhattacharya, Dong, Fabian, & Haenlein, 2021, p. 889) Also, according to Kannan and Li (2017, p. 22), "digital technologies and devices such as smartphones, smart products, the Internet of Things (IoT), Artificial Intelligence, and deep learning all promise significant transformations of consumers' lives in the near future", changing the perspective of marketing from the point of view of companies.

Thus, the teaching and learning process of marketing in the digital context has demanded more and more dynamism to deal with the speed of technological and market transformations that change the employability dynamics and requested labor market skills, for example on the customer success career path or user experience design carreers. Considering this challenging context, the Digital Marketing game emerges, seeking to optimize learning from an active methodology for higher education students of the Business Administration course at a Brazilian university. Aiming to describe the development and application of a game to assist in the teaching-learning of Digital Marketing based on tests with Design Science, this work presents the concepts of gamification and digital marketing, dealing with the methodology used and the game building process.

2 Serious Games and Digital Marketing

The interaction between the social and technological context, contemporary social habits and practices and a native digital generation with precociously stimulated learning abilities drives the increasingly frequent emergence of new educational approaches. As a result, there is an expansion of pedagogical actions in the classroom and the use of games in the educational context is increasingly common (Prensky, 2007; Mcgonigal, 2011; Figueiredo, Paz, Junqueira, 2015).

These new approaches must meet the complexity of teaching and learning relationships in dynamic and active ways, which promote interaction between teachers and students, favoring reflection and dialogue as tools to achieve educational objectives. This playful and interactive model makes students more motivated and engaged, which can promote a deep learning and the development of practical skills such as problem-solving creativity, decision-making and leadership by student-centered learning approaches (Vigotstky, 2010; Challco And Isotani, 2018)

In view of this context, leding to the approach choice, serious games, which refer to the use or adaptation of physical or digital games for pedagogical purposes, allow students to experiment and apply what they learn in real contexts, increasing the relevance of education in their lives (Prensky, 2007; Ortiz-Colón, Jordán, Agredal, 2018; Challco, 2018).

However, for this to happen, strategic planning is needed in the development of a gamified environment, so that benefits such as increased motivation, immersion to enable anticipation and planning of situations are achieved; commitment and socialization through interactivity and interaction (Ortiz-Colón, Jordán, Agredal, 2018; Da Silva, Et Al., 2022).

In the educational field, serious games aim to transmit educational or specific training content through a platform that combines simulation and game elements in a safe environment, providing learning about real subjects, therefore, the purpose is not basic entertainment and in this sense is what differentiates it from other types of games (Alves ,2015).

The well-planned incorporation of gamification in serious games in the classroom allows a more accurate analysis of information, revealing the student's profile and performance. In some cases, it is possible to detect inappropriate behavior in matches with other players, while in other situations it is possible to identify the most evident skills during the learning process, helping in the evaluation process (Alves, 2015; Luz, 2021).

Especially when it comes to teaching digital marketing, it is necessary to devise strategies that are both current, to keep up with the speed with which changes happen, and practices, stimulating the use of marketing techniques and tools in the online context.

We can conceptualize digital marketing as "a promotional activity for either a product or service using digital media." (Daud, Nurjannah, Mohyi, Ambarwati, Cahyono, Haryoko, Handoko, Putra, Wijoyo, Ariyanto and Jihadi, 2022, p. 38). Thus, the insertion of conventional businesses in digital media to build strategies and marketing campaigns in digital channels has become increasingly requested (Daud et al, 2022).

This time, this article will deal with the construction of the use of a serious game, the development of a teaching-learning activity, which uses game elements in a non-game (educational) context through the application of the tools of the development of games for planning these activities (Deterding, Et Al., 2011) engaging students in optimizing digital marketing learning.

3 Methodology

For research development, Design Science was used. The methodology implies developing solutions for concrete problems based on tools and actions. In the present study, a serious game was used to learn digital marketing and its skills. For Sordi, Meireles and Sanches (2010) Design Science is characterized by the rigorous process of planning and creating an artifact that aims to achieve goals, in this case, educational. The problem that was intended to be solved using the method is to develop a game that could be applied in person during class time.

A previous game was applied in the pandemic, however, it was very procedural as it was basically based on fulfilling requirements and distributing points. Despite the fact that it could be applied face-to-face, the game lacked dynamism. To eliminate this restriction, a working group was set up to develop the game of this specific marketing discipline, which aimed to develop the ability to build a marketing plan that took into account aspects of digital marketing. The digital Game MKT, developed through this study, was systematically developed by interactive and constantly validation exchanges. For Venable (2006) the procedures for implementing a Design Science are:

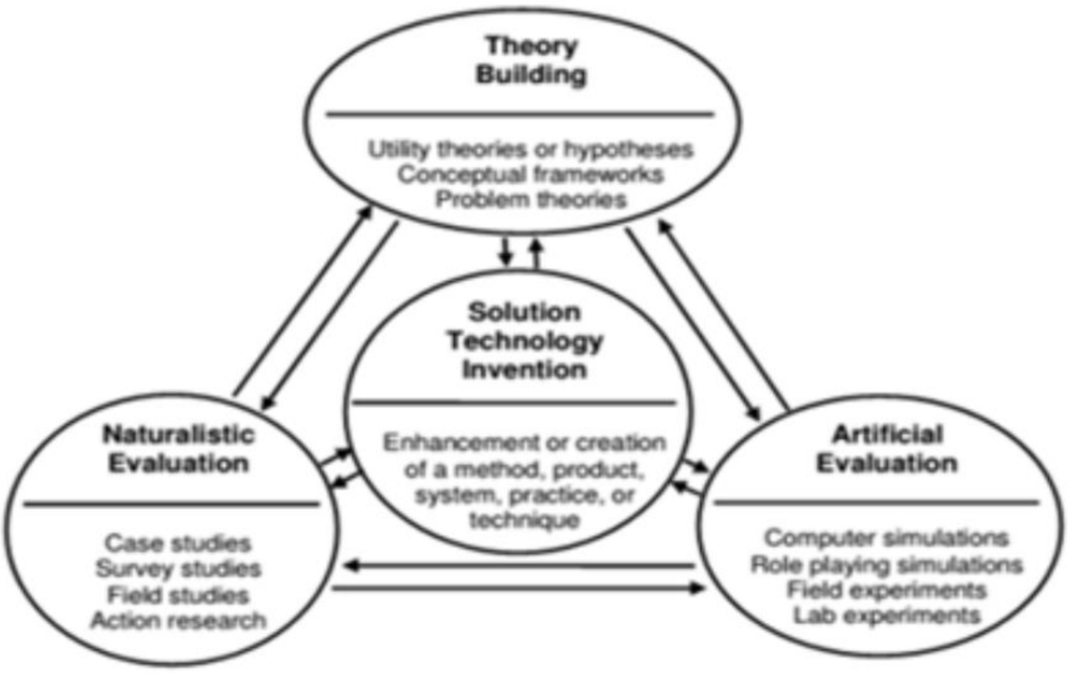


Figure 1: Design Science (Venable, 2006)

According to Venable (2006), problem and solution are placed in the same flow, with confrontation for new possible theoretical developments. Theoretical construction is developed by the progress of foundation-development-validation through analysis of interactions and identification of the problem; by testing the artifact (game) and from the validation of the findings after application in the classroom. Thus, we separate the present investigation into three moments: foundation, natural or artificial evaluation and development, in a circular model of the system.

At the moment of foundation, there is a search for the process of making and selecting the success benchmarks listed in the theory. In this way, the work creates theoretical foundations based on the educational principles of the game. Through the reasoning, the necessary modifications are carried out from the game evaluations (Artificial or by procedural improvement), updating the versions.

4 Data analysis

4.1 Describing the structure of Game MKT Digital

The digital MKT game was conceived based on the constant concerns and searches of the teacher, aiming to associate theoretical knowledge with the need to apply market practices in management activities, considering digital marketing content, knowledge that is constantly evolving.

The game was structured in 4 (four) phases. In the first phase, the groups described the persona's profile and carried out the SWOT and Pestel diagnosis, after this step, the students went on to the next phase, participating in a Quiz with questions related to digital marketing. The third phase consisted of the collection and detailed description of data related to the decisions of the digital marketing channels and the respective actions to be implemented, as well as the definitions of the percentage distributions of investments, with respective justifications for the choices proposed by the group, with the proper presentation of the groups

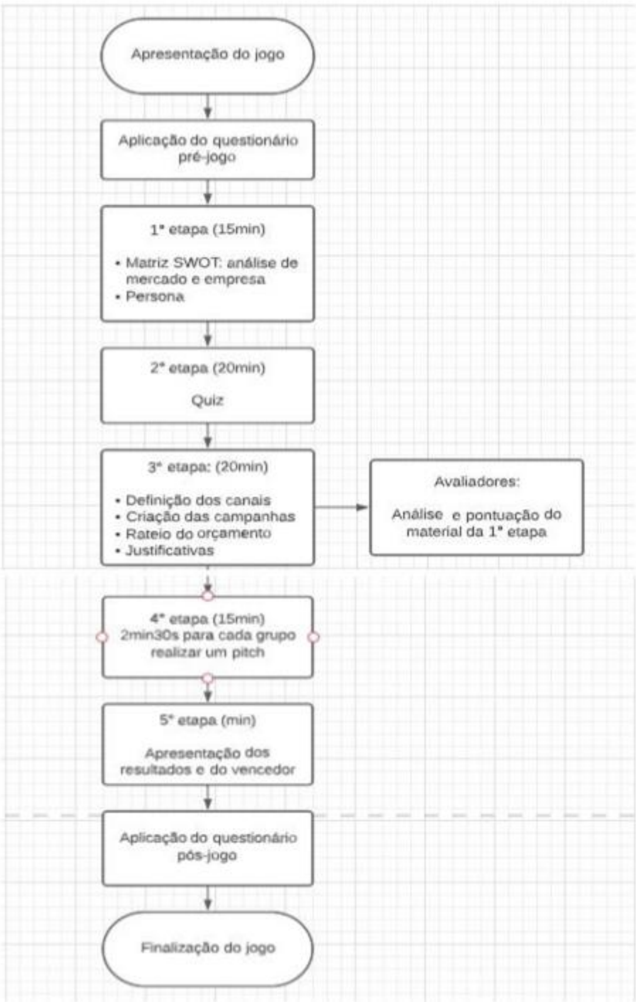


Figure 2: Game stages

Based on this proposal, the professor of the marketing discipline requested the support and participation of the class in its game development, and that's when the class unanimously accepted participation. Soon after, a research instrument was applied with the participants of the discipline in order to assess the initial expectations they had in relation to the application and the impacts on the teaching-learning process.

The classroom was divided into teams, 05 (five) groups were formed, where each one of them was responsible for preparing a task of a phase of the game, in addition to preparing part of the quiz questions. Another team was formed, consisting of a representative appointed by each of the groups, who had the role of guiding the groups in the answers to the main doubts that arose in the development of activities, together with the teacher. This team was also responsible for preparing and inserting evaluation data into an Excel spreadsheet, according to the evaluation criteria for each phase.

In this way, the evaluators went through the groups to carry out the evaluation of the activities and the fulfillment of the actions, in the stages of filling out the forms in addition to entering the data in the other stages of the quiz and the final presentation of the work, all this through the cell phone. They need to fill pre settled free online software to create spreadsheets.

SWOT	G1	G2	G3	G4	G5
Detalhamento e aprofundamento das informações					
Coerência das informações					
Persona					
Detalhamento e aprofundamento das informações					
Coerência das informações					
Quiz					
Pontuação					
Canais e Ações					
Detalhamento e aprofundamento das informações					
Coerência das informações					
Apresentação Peso 2					
Desenvoltura					
Total					

Figure 3: evaluation of the activities

Initially, each group received a “card”, which contained relevant information on the personal and professional attitude of the marketing manager and the profile of the companies, with data referring to: experience, attitude and training of the college's marketing manager; institutional mission and values; quality indicators from the Ministry of Education on the institution and courses; course data; unit location; infrastructure and competitors. One of the groups was selected to prepare the "cards" of the 5 (five) companies offering the same course, a number linked to the number of groups in the classroom, it is emphasized that these educational institutions are real and operate in private education of higher education in Brazil

Figure 4: companies’ profile card

Then, the groups started the first phase of the game, which was to fill out a form that contained the information that was researched both in the “cards” received by the teams, and by information additionally researched on cell phones and computers in the classroom. In this form, the students in the groups, based on the researched data, filled in data about the persona of the course at the educational institution of their respective group, in addition to the data for the construction of the Pestel and SWOT analyses, through information obtained from the companies and from the market. In this phase, each group completed the diagnostic data, after internal discussions, preferably to support the process of dialogue and collective construction, in addition to streamlining the process, through post-its.

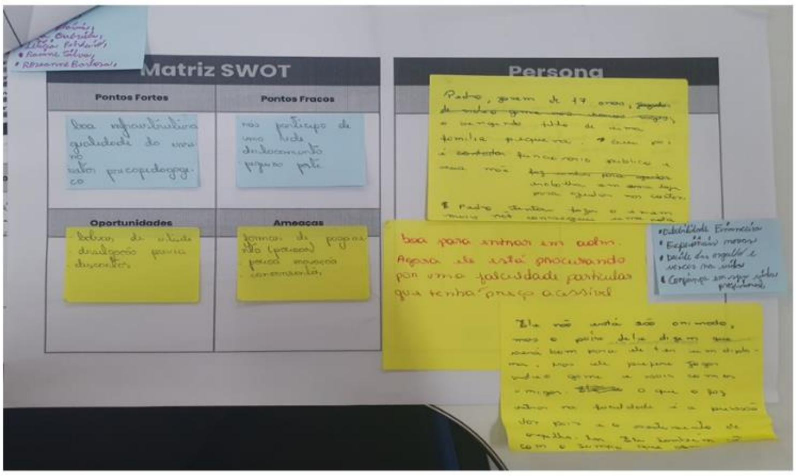
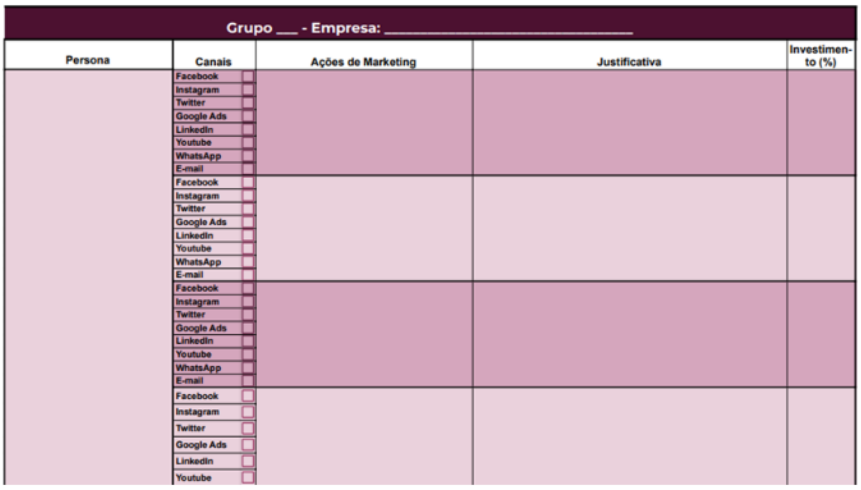


Figure 5: Example of data collection

In the quiz stage, students, who had previously received and read a booklet of questions and answers related to digital marketing, would now have the opportunity to choose, initially, one of the 6 (six) themes of the subject. The themes of the questions were as follows: (1) Persona, traditional and digital marketing; (2) Inbound marketing, sponsored link and content marketing; (3) search marketing and SEO strategy; (4) Sales funnel and purchase journey; (5) Google Ads, Google Analytics and Facebook Ads; and (6) Remarketing and digital marketing metrics. After choosing the theme, the group should choose a number from 1 to 10, in order to select a question linked to the respective subject.

At the end of the quiz phase, the evaluation group presented the partial results of the sum of the scores of each group. In the next phase, all groups received a new form where they had to fill in the information on the digital marketing channels where the companies would make their investments, detailing and justifying the actions to be implemented, as can be seen in figure below.



Grupo ___ - Empresa: ___________________________

Persona	Canais	Ações de Marketing	Justificativa	Investimento (%)
	Facebook Instagram Twitter Google Ads LinkedIn Youtube WhatsApp E-mail			
	Facebook Instagram Twitter Google Ads LinkedIn Youtube WhatsApp E-mail			
	Facebook Instagram Twitter Google Ads LinkedIn Youtube WhatsApp E-mail			
	Facebook Instagram Twitter Google Ads LinkedIn Youtube			

Figure 6: Form to Digital marketing investments

Finally, each group made a general presentation of their analyzes and decisions with the appropriate justifications for the choices, using the presentation model of a Pitch of 5 (five) minutes. Once all presentations are completed, the evaluation team updates the data in the system and presents the winners.

5 Conclusion

The present investigation sought to develop a description of the design process of a gamification artefact for the classroom. The artefact in question was a serious game applied in Brazilian higher education for learning digital marketing. The construction process shows that there was good adherence by the students who participated in the creation of the game and also good academic performance. For future studies it is interesting to apply the same game in different contexts to improve the artefact. This paper aimed to describe this game development as showed above. For future research agenda we suggest to explore the impacts of the game or the differences between other games with same goals.

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6 References

Jan L. Plass, Bruce D. Homer & Charles K. Kinzer (2015) Foundations of Game-Based Learning, Educational Psychologist, 50:4, 258-283, doi: 10.1080/00461520.2015.1122533

Alves, F. (2015). Gamification: como criar experiências de aprendizagem engajadoras. DVS editora.

Challco, G. C., & Isotani, S. (2018). Gamification of collaborative learning scenarios: an ontological engineering approach to deal with the motivation problem caused by computer-supported collaborative learning scripts.

da Silva, A. R. F., Pereira, A. M. F. Fernandes, S. C. S., de Lira, N. E. T., & Bittencourt, I. I. (2022). O Uso da Teoria da Autodeterminação no Contexto da Gamificação. Uma Revisão de Literatura. Revista Latinoamericana de Tecnología Educativa-RELATEC, 21(2), 59-82.

Daud, I. Nurjannah, D. Mohyi, A. Ambarwati, T. Cahyono, Y Haryoko, A, Handoko, A, Putra, R Wijoyo, H. Ariyanto, A. and Jihadi, M. (2022) The effect of digital marketing, digital finance and digital payment on finance performance of Indonesian SMEs.International Journal of Data and Network Science.6.

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011, September). From game design elements to gamefulness: defining" gamification". In Proceedings of the 15th international academic MindTrek conference: Envisioning future media environments (pp. 9-15).

Dominguez , Adrián; Navarette, Joseba Saenz de; Marcos, Luis de; Sanz, Luis Fernández; Pages, Carmen; HerraizZ, José Javier Martínez. (2013) Gamifying learning experiences: Practical implications and outcomes. Journal Computers & Education, Virginia, v. 63, p. 380–392, 2013.

Figueiredo, M. Paz, T. Junqueira, E. (2015). Gamification and education: a state of the art of research conducted in Brazil. Anais do IV Congresso Brasileiro de Informática na Educação - CBIE.

Kapp, K. (2012) The Gamification of Learning and Instruction. Game-Based Methods and Strategies for Training and Education. Pfeiffer, San Francisco, CA.

Luz, V. S. G. D. (2021). Método para ajuste de nível de dificuldade em jogos educacionais fundamentado em aprendizagem de máquina (Master's thesis, Universidade Tecnológica Federal do Paraná).

McGonigal, J. (2011). Reality is broken: Why games make us better and how they can change the world. Penguin.

Ortiz-Colón, A. M., Jordán, J., & Agredal, M. (2018). Gamificación en educación: una panorámica sobre el estado de la cuestión. Educação e pesquisa, 44.

Jan L. Plass, Bruce D. Homer & Charles K. Kinzer (2015) Foundations of Game-Based Learning, Educational Psychologist, 50:4, 258-283, DOI: 10.1080/00461520.2015.1122533

Kannan, P.K. and Li, H.A. (2017) Digital Marketing: A Framework, Review and Research Agenda. International Journal of Research in Marketing, 34, 22-45.https://doi.org/10.1016/j.ijresmar.2016.11.006

Prensky, M. (2007). Digital Game-Based Learning . St. Paul - MN, USA: Paragon House. 2007.

Verhoef, P., broekhuizen, T. , bart, Y., Bhattacharya, A., Dong, J., Fabian, N., Haenlein, M. (2021) Digital transformation: A multidisciplinary reflection and research agenda.Journal of Business Research. 122.

Vigotsky, L. S (2010). A formação social da mente: O desenvolvimento dos processos psicológicos superiores; Michael Cole. [et al.] (Org). 7. ed. São Paulo: Martins Fontes, 2007. 4ª tiragem.

Venable, J. R.(2006) The Role of Theory and Theorising in Design Science Research. In: International Conference on Design Science Research in Information Systems and Technology – Desrist.

Vianna, Ysmar et al. (2013) Gamification, Inc: *como reinventar empresas a partir de jogos* Rio de Janeiro: MJV

Sordi, J. O.; Meireles, M.; Sanches, C.(2010) Design Science aplicada às pesquisas em Administração: Reflexões a partir do recente histórico de publicações Internacionais. Revista de Administração e Inovação, São Paulo, v. 8, n. 1, p.10-36.

Safety Culture in Higher Education Institutions: Knowledge and Training preferences

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Abstract

The development of a positive culture is a key element within an organization to achieve performance against a strategic objective. In terms of safety, universities play a very important role in training new professionals who must be increasingly aware and prepared for the challenges of the labour market and daily activities. Therefore, this study aims to assess the safety culture of newcomer students to higher education through the application of a 22-item questionnaire. Participants included 109 undergraduate and master's students from 31 different courses at a university in Northern Portugal. It was observed that the level of knowledge varied according to the type of course adopted and the gender of the student. A global performance level of below 80% shows that safety knowledge can improve further. Additionally, different preferences concerning the content, moment, and format of safety training were presented. The low level of interest in training related to chemical leakage, suspicious package, and bombing show participants may attribute a low probability level to these events. In conclusion, this work shows that it can be useful for universities to consider different training approaches according to different course types.

Keywords: Safety Culture; Higher Education Institutions; Safety Education; Emergency; Portugal

1 Introduction

Safety culture concerns the way people act, think and behave in relation to safety (Jeffcott et al., 2006). Basically, it is created and disseminated within an organization through the policies, practices and procedures adopted by it. How these measures are put in place and their alignment with organizational objectives will determine the impact of safety culture on overall performance. In this sense, the development of a positive safety culture plays a key role in any organization.

As a complex, multi-, and inter-disciplinary aspect, safety culture can be approached in different manners. In the academic environment, it has been studied from various perspectives, such as Emergency Situations (Hasan & Younos, 2020), Road Safety (Hasan & Younos, 2020), First Aid (Jamaludin et al., 2018), Laboratory Safety (Kou et al., 2021), Patient Safety (Çiftcioğlu et al., 2022; Lee et al., 2018), among others. Assessing the safety culture in educational institutions is key to determining their level of preparedness and reasoning when facing safety-related situations.

Examples of studies focused on safety culture in higher education institutions include Gong (2019), Zhao et al. (2022), and Gao et al. (2022) who investigated the level of safety culture of students at Chinese universities, and Hasan & Younos (2020) who investigated the level of safety culture amongst Bengali students. Other authors that investigated safety culture in universities were Nor Kamilah et al. (2019) in Malaysia, Khalid et al. (2022) in the United Arab Emirates, and Lavasani & Khandan (2021) in Turkey.

In Portugal, only the studies of Inácio (2010), Silva (2016), and Mota (2019) addressed the safety culture in educational institutions. However, none of them investigated higher education institutions. For example, Inácio

(2010) and Silva (2016) dedicated themselves to evaluating the safety culture of primary-level students (i.e., 1st to 9th school years), while Mota (2019) focused on secondary-level students (i.e., 10th, 11th and 12th school years).

Based on the importance of safety culture in academic environments and the lack of studies in Portugal's higher-level education, the current study evaluated the background, knowledge and preferences of 109 students in relation to emergency situations. This was done through a 22-question questionnaire, which assessed the level of safety culture among 1-year undergraduate and master's students in a Portuguese university.

2 Material and Methods

Based on the proposed research objective of investigating the level of safety culture in a Portuguese high-education institution concerning emergency situations, the present study employed an online questionnaire aimed at first-year undergraduate and master's students from the University of Minho (UM) in Portugal. UM has approximately 19,000 students divided between undergraduate, integrated and isolated masters and doctoral students. It has approximately 43 undergraduate courses and 18 integrated masters, which are distributed across three campuses in Northern Portugal (UMinho, 2023).

2.1 Sample size

The sample size was established according to the total number of first-year undergraduate and integrated master's students at UM of approximately 3000 students. As Israel (1992) proposed, the sample size was calculated through Equation 1.

$$n_o = \frac{Z^2 p * q}{e^2} \qquad \textit{Equation } 1$$

Where Z is the abscissa of the normal curve that cuts off an area α at the tails (1 - α equals the desired confidence level, e.g., 90%); p is the estimate proportion of an attribute that is present in the population; q is equal to 1- p; and e is the level of precision (e.g., 10%).

2.2 Questionnaire development

A 22-item questionnaire was developed to determine the level of knowledge, attitudes and behaviour of students concerning emergency situations. The survey, which was developed only in Portuguese, was prepared and structured on the Google Forms online platform. The questionnaire development was based on literature review studies (e.g., Hasan & Younos (2020), Gao et al. (2022), and Inácio (2010)) and also took into account experts' opinions (professors and safety professionals). The questionnaire validation process consisted of two iterative steps. First, professors and health and safety professionals helped to check the relevance of the questions. Second, four students responded to the questionnaire to verify if it was adapted to the reality of the respondents. After three versions, the questionnaire reached its final version with 22 questions and an average response time of 5 minutes. The questionnaire was composed of four parts, namely, Part I – Socioeconomic aspects (4 questions), Part II – Background (5 questions), Part III - Safety Knowledge (9 questions), and Part IV - Expectations regarding emergency situations (4 questions).

2.3 Data Collection

The questionnaire was disseminated by sending an email to the general directory of students, where all UM students, regardless of their level of study (undergraduate, master's or doctorate) were notified. The data collection period was carried out from February 19 to April 12, 2019. A total of 226 students answered the questionnaire. Each student that agreed to participate in this study did so voluntarily after being informed about the research purpose, methods, and the anonymity of obtained data before responding to the questionnaire.

The eligibility criteria used in this study were (1) participants had to be over 18 years old, and (2) participants should be students attending the 1st year of undergraduate degrees or integrated masters. The objective of selecting only first-year undergraduate or integrated master's students was due to the composition of the primary and secondary education national curriculum. In Portugal, primary education students receive training and take safety-related courses. Therefore, to capture the level of student safety culture acquired throughout this education process, only students who had recently entered in higher education were selected. Therefore, after applying the eligibility criteria, 109 answers were included in the final analysis.

2.4 Data Analysis

All data collected was exported to, stored, and analysed in Microsoft Excel 2016. The data analysis process was performed using both SPSS Statistics software, version 25 (SPSS Inc., Chicago, IL, USA) and Excel 2016 (Microsoft®). For simplification purposes, participating courses were grouped into three categories, as shown in Table 1.

Table 1 - Courses' categorization.

Category	Participants' courses	Number of courses
Biological Sciences	Degree Applied Biology; Degree in Biology and Geology; Degree in Nursing; Integrated master's in Medicine.	4
Exact Sciences	Degree in Biochemistry; Degree in Computer Science; Degree in Product Design; Degree in Applied Statistics; Integrated Master in Civil Engineering; Integrated Master in Materials Engineering; Integrated Master in Polymer Engineering; Integrated Master in Information Systems Engineering and Management; Integrated Master in Industrial Engineering and Management; Integrated Master in Industrial Electronics and Computers Engineering; Integrated Master in Computer Engineering; Integrated Master in Mechanical Engineering.	12
Human Sciences	Degree in Public Administration; Degree in Political Science; Degree in Communication Sciences; Degree in Criminology and Criminal Justice; Law degree; Degree in Economics; Degree in Education; Degree in Cultural Studies; Degree in Geography and Planning; Degree in management; Degree in Applied Languages; Degree in European Languages and Literature; Degree in Marketing - Post-Work; Degree in International Relations; Integrated master's in psychology.	15

3 Results

The final participants' sample of 109 refers to a confidence level of 90% and a level of precision of 10% assuming the total population 3,000 students. The final sample is above the minimum sample size of 97 obtained through Equation 1 for the aforementioned confidence level and precision.

3.1 Socio-demographic

Considering the 109 subjects participating in the sample, 56 were male (51.4%) and 53 were female (48.6%), with an average male age of 19.3 ± 2.9 years old and an average female age of 21.3 ± 5.7 years old. About the composition of the students sample, 93.5% were Portuguese students and 6.5% were foreign students. Fifty-seven per cent of foreign students consisted of Brazilian nationals followed by Cape Verdeans (14.3%), Russians (14.3%) and Ukrainians (14.3%). With respect to the district of origin, among Portuguese students 60.8% were from Braga District, 17.6% from Porto, 11.8% from Viana do Castelo, 2.0% from Leiria and Vila Real, and 1.0% from Guarda and Aveiro.

3.2 Background

In relation to students' academic background, from the 109 subjects participating in the sample, 57.8% (n=63) were taking courses in the field of Exact Sciences, 33.0% (n=36) in Human Sciences, and 9.2% (n=10) in Biological Sciences. In total, 31 courses participated in this study.

Concerning work experience, 50.9% (n=27) of females and 33.9% (n=19) of males performed some type of remunerated activity (e.g., job or internship). Of the 46 students that affirmed having any type of work experience, 17 stated they have received some type of training related to safety.

3.3 Safety Knowledge

Within Part III of the questionnaire, a total of 9 questions were used to determine students' knowledge of safety. Performance was established based on the number of correct answers from each participant in relation to the section's total (i.e., 9 questions). Table 2 shows these results aggregated by course and gender.

Table 2 - Safety Knowledge Performance levels according to course and gender.

Category/Gender	Safety Knowledge Performance
Biological Sciences (n=10)	**88.9%**
Female (n = 6)	*81.5%*
Male (n = 4)	*100.0%*
Exact Sciences (n=63)	**79.0%**
Female (n = 24)	*83.8%*
Male (n = 39)	*76.1%*
Human Sciences (n=36)	**74.7%**
Female (n = 23)	*75.8%*
Male (n = 13)	*72.6%*
Female (n=53)	**80.1%**
Male (n=56)	**77.0%**

Women presented a global performance of 80.1% whilst men 77.0%. Participants from Biological Sciences had the best performance amongst all categories (88.9%), followed by Exact Sciences (79.0%) and Human Sciences (74.7%).

3.4 Safety training

Part IV of the questionnaire, consisting of 4 questions, sought to understand the student's training interests in relation to safety. In general, the topic that most aroused the students' interest was “gas leakage” (n=107 or 98.2%), followed by “violence” (n=96 or 88.1%), “personal accidents” (n=91 or 83.5%), “evacuation” (n=89 or 81.6%), “fire” (n=88 or 80.7%), “bomb threat” (n=85 or 77.9%), “suspicious package” (n= 76 or 72.5%) and “leakage of chemicals” (n= 74 or 67.9%). It is worth mentioning that the respondents had access to the definition of each one of these categories.

The level of interest in Safety training was also observed through the effect of the course category (i.e., Biological Sciences, Exact Sciences and Human Sciences). It was observed that the participants in the Biological Sciences category were the ones who showed the highest level of interest across all training (87.5%), except for Evacuation, followed by Exact Sciences with 78.8%, and Human Sciences with 78.1%. This can be seen in Figure 1, where it is presented the percentage of participants that showed interest in participating in different training by category.

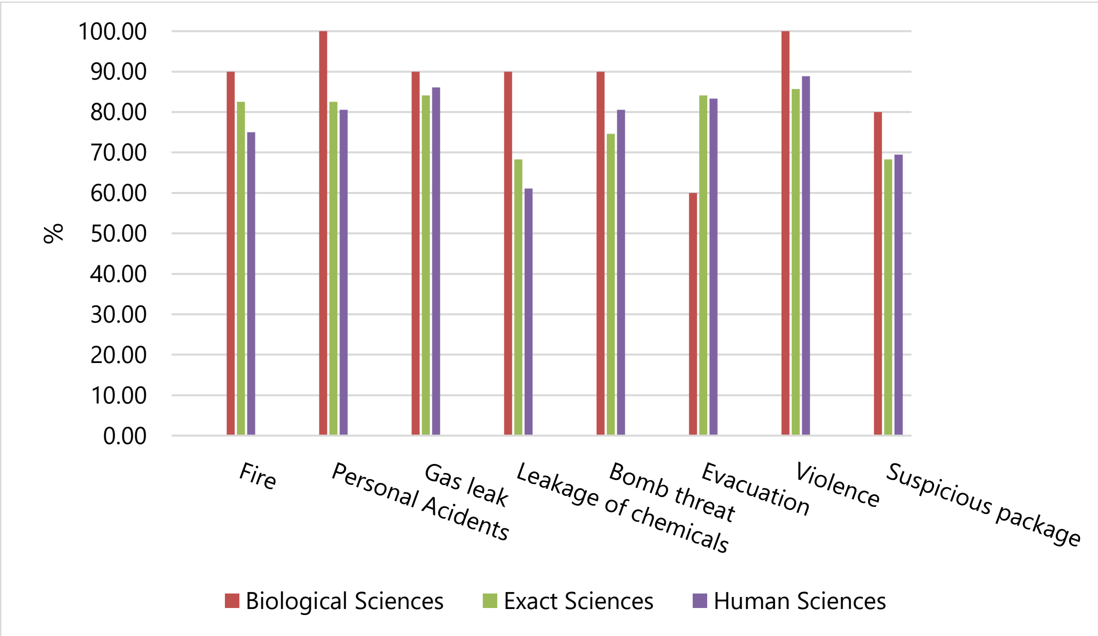

Figure 1 – Preferences concerning the training content by course category.

In question 19, students were asked about the most relevant moment for learning the topic. In general, students had the propensity to choose "Annually" (45.0%) and "At the beginning of the course" (45.0%) as the most relevant moments to learning the emergency subject. In view of the effect of gender, it was not observed differences between the choice of the most relevant moment when comparing males and females, being both divided within "Annually" (male: 44.6%, female: 45.3%) or "At the beginning of the course" (male: 42.9%, female: 47.2%).

However, when considering the effect of the course category, it was observed that was an inclination of Biological and Exact Sciences to choose "At the beginning of the course" as the most relevant moment, while

Human Sciences preferred "Annually". Table 3 shows these results aggregated by course, gender, and moment of training.

Table 3 – Preferences concerning the moment of safety training by course category and gender.

Category/Gender	Moment of training				
	Annually	At the end of course	At the beginning of the course	In the middle of the course	Null
Biological Sciences (n=10)	**40.0%**	**0%**	**60.0%**	**0%**	**0%**
Female (n = 6)	*16.7%*	*0%*	*83.3%*	*0%*	*0%*
Male (n = 4)	*75.0%*	*0%*	*25.0%*	*0%*	*0%*
Exact Sciences (n=63)	**44.4%**	**1.6%**	**47.6%**	**4.8%**	**1.6%**
Female (n = 24)	*41.7%*	*0%*	*50.0%*	*4.2%*	*4.2%*
Male (n = 39)	*46.2%*	*2.6%*	*46.2%*	*5.1%*	*0%*
Human Sciences (n=36)	**47.2%**	**0%**	**36.1%**	**11.1%**	**5.6%**
Female (n = 23)	*56.5%*	*0%*	*34.8%*	*8.7%*	*0%*
Male (n = 13)	*30.8%*	*0%*	*38.5%*	*15.4%*	*15.4%*
Female (n=53)	**45.3%**	**0.0%**	**47.2%**	**5.7%**	**1.9%**
Male (n=56)	**44.6%**	**1.8%**	**42.9%**	**7.1%**	**3.6%**

As for the preferences of the students in relation to the most propitious arrangement to receive the formation, most of the students preferred workshop (n=37.6%), followed by short-term seminar (n=22.0%), curricular units (n=19.3%), extracurricular units (n=11.9%) and, lastly, optional curricular units (n=7.3%). The “workshop” was described as having both theoretical and practical components with a duration lesser than 2 days. The “seminar” was described as having a duration lesser than 1 day.

Regarding the course category, it was observed that there was an inclination of Biological (n=70%), Exact (n=31.7%) and Human Sciences (n=38,9%) to choose the "workshop" format as the best learning arrangement. The second most chosen option was the "curricular unit" to Biological (n=30%) and Human Sciences (n=25%), while Exact Sciences preferred “short-term seminars” (n=27%). With reference to the effect of gender on choice, it was noticed that was a preference for both, males and females to choose "workshop" as the best format. Table 4 shows these results aggregated by course, gender, and format of training.

Table 4 – Preferences concerning the format of safety training in relation to course category and gender.

Category/Gender	Training format					
	Short-term seminar	Extracurricular Units	Optional Curricular Units	Curricular Units	Workshop	Blank
Biological Sciences (n=10)	**0%**	**0%**	**0%**	**30.0%**	**70.0%**	**0%**
Female (n = 6)	*0%*	*0%*	*0%*	*50%*	*50%*	*0%*
Male (n = 4)	*0%*	*0%*	*0%*	*0%*	*100%*	*0%*
Exact Sciences (n=63)	**27.0%**	**15.9%**	**9.5%**	**14.3%**	**31.7%**	**1.6%**
Female (n = 24)	*33.3%*	*12.5%*	*8.3%*	*16.7%*	*25%*	*4.1%*
Male (n = 39)	*23.1%*	*18.0%*	*10.3%*	*12.82%*	*35.9%*	*0%*
Human Sciences (n=36)	**19.4%**	**8.3%**	**5.6%**	**25.0%**	**38.9%**	**2.8%**
Female (n = 23)	*30.4%*	*4.3%*	*8.7%*	*21.7%*	*34.8%*	*0%*
Male (n = 13)	*0%*	*15.4%*	*0%*	*30.8%*	*46.2%*	*7.7%*
Female (n=53)	**16.1%**	**16.1%**	**7.1%**	**16.1%**	**42.9%**	**1.8%**
Male (n=56)	**28.3%**	**7.5%**	**7.5%**	**22.6%**	**32.1%**	**1.9%**

4 Discussion

In general, women presented higher safety knowledge scores than men (80.1% *v*. 77.0%, Table 2). This relationship was also observed in other studies, such as Al-Surimi et al. (2018), Çiftcioğlu et al. (2022) and Gao et al. (2022). However, this behavior was not observed in Lavasani & Khandan (2021), where authors did not notice any differences between males' and females' safety knowledge. Particularly, Human Sciences presented the lowest safety knowledge performance (74.7%), which indicates a gap of 14 percentage points in relation to the best performance (Biological Sciences, 88.9%). This points out to the necessity of levelling safety knowledge across different fields of study. Moreover, a global performance below 80% shows that safety knowledge can improve further as students advance their studies within the university.

With respect to the preferences of the students (Figure 1), Biological Sciences was the course category that showed the greatest interest in all safety training topics, except for "Evacuation". This may be related to the background of the students, since the courses in this category (Table 1) are courses that work directly with people or animals (e.g., nursing or medicine). Another reason may be the type of course adopted in secondary education, which, depending on the choice, restricts or emphasizes a certain curriculum.

In the case of Exact Sciences, students showed a very low level of interest in the "Leakage of chemicals", "Bomb threat", and "Suspicious package" (Figure 1). The low level of interest in the "Leakage of chemicals" training may be related to the fact that throughout secondary education students have already exhausted the subject. In the case of "Bomb threat" and "Suspicious package", the low level of interest may be related to the fact that students have never witnessed or experienced any situation involving such components, which results in a lower collective perception of its danger and the attribution of a lower event probability. This would be probably different in a country that is a victim of a terrorist attack, for instance, as shown by Nilsen et al. (2018).For Human Sciences, students also showed a low level of interest in the "Leakage of chemicals" and the "Suspicious package". As in the case of Exact Sciences, the reason for this may be related to the fact that students have never witnessed or experienced a similar situation.

5 Conclusion

This study included 109 participants from a university located in Northern Portugal, encompassing a student population from 31 different courses. The participants' sample represented well the university 1st-year undergraduate and 1st-year integrated master's population (n=109 in current study *v.* N=3000 in the university; confidence level = 90% and level of precision = 10%). A 22-question questionnaire evaluated the background, knowledge, and preferences of 1-year students to assess the safety culture of newcomers in higher education in terms of emergency situations.

This was motivated by the lack of studies in the area, as well as the importance of safety-aware professionals in the labour market and day-to-day activities at educational institutions. It was observed that the level of knowledge varied due to the type of course and the student's gender. Safety knowledge can improve significantly as students advance their academic life. Likewise, students from different fields of study presented different preferences concerning the content, moment and format of safety training. This points to one of the main implications of this work related to the consideration of different training approaches according to different types of courses and the investment in further safety training.

As to limitations, this study focused only on the aspect related to emergencies, leaving aside important topics such as traffic safety, first aid, etc. Another limitation of this work was the sample population, which, although not small, could have benefited from better statistical robustness. As a proposal for future work, the safety culture could be analyzed from the point of view of the whole organization, evaluating the safety culture of teachers, laboratory technicians and other functions involved in the academic environment in relation to the practices, policies and procedures in terms of safety adopted by the educational institution. This would provide a measure of the safety preparedness of the whole organization and identify points for improvement.

6 References

Al-Surimi, K., Alayadi, H., & Salam, M. (2018). Female dental students' perceptions of patient safety culture: A cross sectional study at a middle eastern setting. *BMC Medical Education*, *18*(1). https://doi.org/10.1186/s12909-018-1415-8

Çiftcioğlu, Ş., Apaydın Cırık, V., & Efe, E. (2022). Student nurses' perceptions of a patient safety culture: A descriptive and cross-sectional study. *Perspectives in Psychiatric Care*, *58*(2), 658–663. https://doi.org/10.1111/ppc.12830

Gao, S., Chang, C., Ren, F., & Yu, F. (2022). Safety Culture Measurement Among Chinese Undergraduates at a Private University: Development and Validation. *Frontiers in Public Health*, *10*. https://doi.org/10.3389/fpubh.2022.825106

Gong, Y. (2019). Safety culture among Chinese undergraduates: A survey at a university. *Safety Science*, *111*(May 2018), 17–21. https://doi.org/10.1016/j.ssci.2018.09.010

Hasan, M. K., & Younos, T. B. (2020). Safety culture among Bangladeshi university students: A cross-sectional survey. *Safety Science*, *131*. https://doi.org/10.1016/j.ssci.2020.104922

Inácio, M. C. A. G. (2010). *A promoção de uma cultura de segurança nos alunos do ensino básico: um estudo de caso nos segundo e terceiro ciclos*. Universidade de Coimbra.

Israel, G. D. (1992). *Determining Sample Size*. https://doi.org/10.1177/104973200129118183

Jamaludin, S., Soe, T., Allif, M., Zakaria, B., Saidi, S., & Chan, C. M. (2018). A Literature Review On Knowledge , Awareness and Attitude Related To First Aid Among University Students Scholars Journal of Applied Medical Sciences (SJAMS) Surgical Nursing A Literature Review On Knowledge , Awareness and Attitude Related To First Aid. *Scholars Journal of Applied Medical Science*, *6*(7), 2659–2664. https://doi.org/10.21276/sjams.2018.6.7.10

Jeffcott, S., Pidgeon, N., Weyman, A., & Walls, J. (2006). Risk, trust, and safety culture in U.K. train operating companies. *Risk Analysis*, *26*(5), 1105–1121. https://doi.org/10.1111/j.1539-6924.2006.00819.x

Khalid, K., Khalid, K., & Davidson, R. (2022). A multi-group assessment of safety culture among engineering students in the United Arab Emirates. *Journal of Engineering, Design and Technology*.

Kou, Y., Peng, X., Dingwell, C. E., Reisbick, S. A., Tonks, I. A., & Sitek, A. A. (2021). Learning Experience Reports Improve Academic Research Safety. *Journal of Chemical Education*, *98*(1), 150 – 157. https://doi.org/10.1021/acs.jchemed.0c00133

Lavasani, M. G., & Khandan, F. (2021). A research on the knowledge level and safety culture of students taking occupational. *Cypriot Journal of Education*, *16*(1), 187–200.

Lee, H.-Y., Hahm, M.-I., & Lee, S. G. (2018). Undergraduate medical students' perceptions and intentions regarding patient safety during clinical clerkship. *BMC MEDICAL EDUCATION*, *18*. https://doi.org/10.1186/s12909-018-1180-8

Mota, A. cristina oliveira santos batista da. (2019). *Promoção De Uma Cultura De Segurança No Ensino Secundário – Estudo De Caso Aplicado Ao Concelho Do Seixal*. ISEC Lisboa Instituto Superior De Educação e Ciências.

Nilsen, M., Albrechtsen, E., & Nyheim, O. M. (2018). Changes in Norway's societal safety and security measures following the 2011 Oslo terror attacks. *Safety Science*, *110*, 59–68. https://doi.org/https://doi.org/10.1016/j.ssci.2017.06.014

Nor Kamilah, M., Balakrishnan, P., Mohd Nazri, Z., Ahmad Rasdan, I., & Aryana, S. (2019). Determining factors on technical instructors' safety culture using structural analysis approach. *Jurnal Kejuruteraan*, *2*(1), 35–43.

Silva, A. E. A. da. (2016). *O Envolvimento dos alunos no diagnóstico de Higiene e Segurança em parques escolares*. University of Minho.

UMinho. (2023). *UMinho*. https://www.uminho.pt/PT/uminho

Zhao, W., Zhou, Z., & Jiang, H. (2022). The Mechanism of Safety Culture Construction in Chinese Universities Based on POI Data and Gravity Model. *Advances in Multimedia*, *2022*. https://doi.org/10.1155/2022/8223516

Game development learning with PBL approach as a tool to assess computer engineering competences.

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Abstract

This paper presents strategies for a Game Development course that aims to develop hard and soft skills in computer engineering students. There is a focus on soft skills that are considered essential for success in the 21st-century professional world. The design for this course is based on the Project-Based Learning approach, which allows students to explore different techniques and encourages creativity, while still having clear objectives and pre-defined milestones. The article discusses the use of continuous monitoring, peer assessments, and the Agile project approach to evaluate student progress and ensure that each student experiences different roles in project management.

Keywords: Game Development; Project-Based Learning, Soft Skills, computer engineering

1 Introduction

It is increasingly important for professionals to be prepared, not only in teach technical skills, commonly called hard skills but also in the skills known as soft skills, considered essential for the 21st-century professional (Sreehari, 2021). However, while hard skills are simpler to evaluate, soft skills present a much greater challenge, due to their qualitative and indirect nature (Yousef, Elzamly, Doheir, & Yaacob, 2022).

With these challenges in mind, an undergraduate Game Development course has the environment to bring a holistic approach to the student, with a curriculum designed to develop and reinforce the various skills expected of computer engineering students. The designed course proposes to go through the entire game production pipeline, starting with board games and moving on to 2D and 3D video games. Throughout this journey, students are presented with various content and skills that will eventually solidify into professional competencies. This course was designed based on the proposal of Project-Based Learning, which presents students with a base project, with a defined time and scope, but still encourages creativity so that they can carry out different proposals and explore various techniques freely (Salibi, Machado, Rodrigues, Souza, & Campos, 2021).

As the field of Games Development is broad and the creation of a functional prototype is complex and requires various skills, each project is presented with clear objectives aimed at developing the skills considered necessary for progression in the course, with pre-defined milestones and regularly evaluated through continuous monitoring and peer assessments

The proposed continuous monitoring follows the Agile project approach (Beck, et al., 2001), in which each group must define various project points and tasks to be completed by the next week. During these meetings, professors have the opportunity to evaluate various aspects of each student and the group as a whole. In the final projects, there is a rotation of roles among those pre-defined for project management. The objective here is to ensure that each student has a complete experience in each of these roles, further encouraging the development of the necessary soft skills for the project to be delivered on time and with quality (Duch, Allen, & Harold, 1997).

This article aims to qualitatively present the impact of these decisions on the quality of project delivery, in various areas such as: completeness, cohesion, absence of bugs, and application of the presented content.

2 Literature Review

The literature review aided in establishing clear objectives, identifying best practices for teaching and learning, and assisting in evaluating students' needs. This made it possible to create a program that meets the expectations of students while achieving positive learning outcomes.

2.1 Soft Skills

To train a well-rounded professional in the field of computing, it is necessary to give proper attention not only to technical skills, also known as hard skills, but also to interpersonal skills, commonly referred to as soft skills, such as critical thinking, problem-solving, continuous learning, cooperation, and communication. Duch, Allen, & Harold (1997) argue that these skills are fundamental to future professional success. Moreover, Sreehari (2021) highlights that many Human Resources managers prioritize professionals with developed interpersonal skills, even if their technical skills are not as advanced. In the field of software engineering, Yousef (2022) emphasizes that it is crucial for teams to master both technical and interpersonal skills to manage projects efficiently.

2.2 Game Development Teaching

The development of digital games as a teaching tool has proven to be an efficient way to provide interdisciplinary challenges to students (Salibi, Machado, Rodrigues, Souza, & Campos, 2021). Games can vary in scope, ranging from simple arcade games to more complex games that require large teams of specialized professionals. This possibility of continuous scaling of complexity offers a highly dynamic learning environment (Guimaraes & Murray, 2008). Furthermore, digital games have great motivational potential for students (Cagiltay, 2007), which can lead to greater absorption of knowledge in various areas. Through games, it is possible to assess skills and knowledge in areas such as object-oriented programming, software architecture, and management, among others, in a playful and enjoyable way. Because of this, digital games have become an important tool in education, stimulating learning and the development of diverse skills and competencies.

2.3 Agile Project Management

Agile is widely recognized as an umbrella term encompassing a variety of methodologies used in project management, including Scrum and Extreme Programming. It places a strong emphasis on fast iterative processes, collaboration, and self-managed teams. Based on the seminal works of Beck et al. (2001), Agile prioritizes key values such as individuals and interactions, working software, customer collaboration, and responding to change. The benefits observed in industry settings extend to the realm of education, particularly in the classroom environment. Implementing Agile principles in the classroom fosters a collaborative environment, improving communication and promoting active participation (S. Al-Ratrout, 2019). This approach has shown to create a better learning environment by enhancing students' ability to work together, share ideas, and actively engage in the learning process. By embracing Agile practices in education, students are better prepared for future teamwork and collaboration in professional settings.

2.4 Assessment

Game development is a complex activity that involves several aspects, from the conception of ideas to the implementation of game mechanics, graphics, and sound. To assist in teaching these aspects, the Project-Based Learning approach has been widely used, where students learn through the development of projects with a longer elaboration time, going through the phases of Planning, Execution, and Judgment (Salibi, Machado, Rodrigues, Souza, & Campos, 2021). Along with PBL, Team-based Learning is a strategy that can be adopted to enhance the assessment of students' soft skills during the game production process. It is important to note that all projects are accompanied by a well-defined rubric, which should be based on the construction process, as cautioned by Hattingh (2022). In this way, we seek to avoid the ticking-boxes execution process, that is, the simple fulfilment of pre-established tasks in the rubric, to the detriment of learning. To encourage motivation and create a portfolio for future employers, students delivered their final projects in a Game Jam, that is hosted in the itch.io[7] platform. This proposal allowed students to demonstrate their abilities and provided a platform to showcase their work to a wider audience. The creation of a portfolio serves as a valuable tool for future employment opportunities and can serve to motivate students to continually develop their skills (Fernandes, Abelha, & Albuquerque, 2022). The use of itch.io as a platform for the delivery and display of the final projects allowed students to showcase their work to potential employers and further encourage their development. The integration of these pedagogical approaches can be extremely beneficial for the learning of computer engineering students in game production.

3 The Course

The course development was conceived in order to allow for a comprehensive evaluation of the various elements of knowledge that the student should acquire and apply throughout the semester. To achieve this goal, the course is organized into four moments, as described in Table 1. The first stage aims at introducing the fundamental concepts of game design, followed by a practical challenge of creating a simple board game, which aims to solidify the concepts of mechanics, balancing, and play-testing. The second stage addresses the use of a specific game engine platform. The selected game engine selected for the platform was Unity[8]. Students have the first contact with the platform through the completion of the official Unity learn tutorial "Roll-A-Ball", which offers the opportunity to explore the main concepts used in the tool and expand knowledge through the creation of new mechanics. In the third stage, students are challenged to design an open-themed 2D game in pairs, following the proposal for the creation and analysis of the DDE proposed by Walk, Görlich, & Barrett (2017). Finally, in the fourth stage, the challenge of creating a mobile game with an advertising monetization concept is introduced, aiming to stimulate students' interest in producing digital games while providing the opportunity for practical application of monetization knowledge in real projects. The course was designed with the objective of providing solid and comprehensive training in game design, stimulating creativity and innovation, and preparing students for an increasingly demanding and dynamic job market.

Table 1. Course Outline

#	Weeks	Project	Key Concepts
1	4	Boardgame	Mechanics, Dynamics, Core Gameplay loop, Playtesting
2	4	Roll-A-Ball	Unity, OOP, Design Patterns for games
3	6	2D	Design Docs, DDE, Types of players
4	6	Final	Optimizations, Responsive UI, Marketing & ADs

[7] https://itch.io/

[8] https://unity.com/

3.1 Boardgame

In the context of game development, it is common for students to encounter complex concepts such as dynamic mechanics and balancing, which require a certain degree of skill for their understanding and application. With the aim of facilitating the understanding of these concepts and encouraging students' creativity, an initial challenge was proposed in which students must create a complete board game, with pieces, board, and a rule book. To validate their projects, each student is required to participate in a playtest model wherein they evaluate games developed by their peers. During this process, one member of the group assumes the role of an observer while students from different groups engage in playing the game. The observer's task is to carefully monitor the playthrough without interacting or providing explanations about the game. Instead, their role primarily involves making detailed annotations regarding the playthrough experience. After a designated period, the players are prompted to rate the game they have just played and offer structured feedback. This feedback is intended to provide constructive criticism and valuable insights for further refinement of the game. The structured nature of the feedback ensures that key aspects such as gameplay mechanics, user experience, aesthetics, and overall satisfaction are comprehensively evaluated. By incorporating this playtest model into the assessment process, we aim to foster a culture of constructive collaboration, allowing students to benefit from diverse perspectives and refine their games based on critical feedback. A playtest session can be seen in Figure 1. After receiving feedback from their peers, students are encouraged to revise their projects before the final submission and evaluation. This teaching-learning model aims to provide students with a creative and dynamic environment in which they can learn and apply important game development concepts in a practical and interactive way.

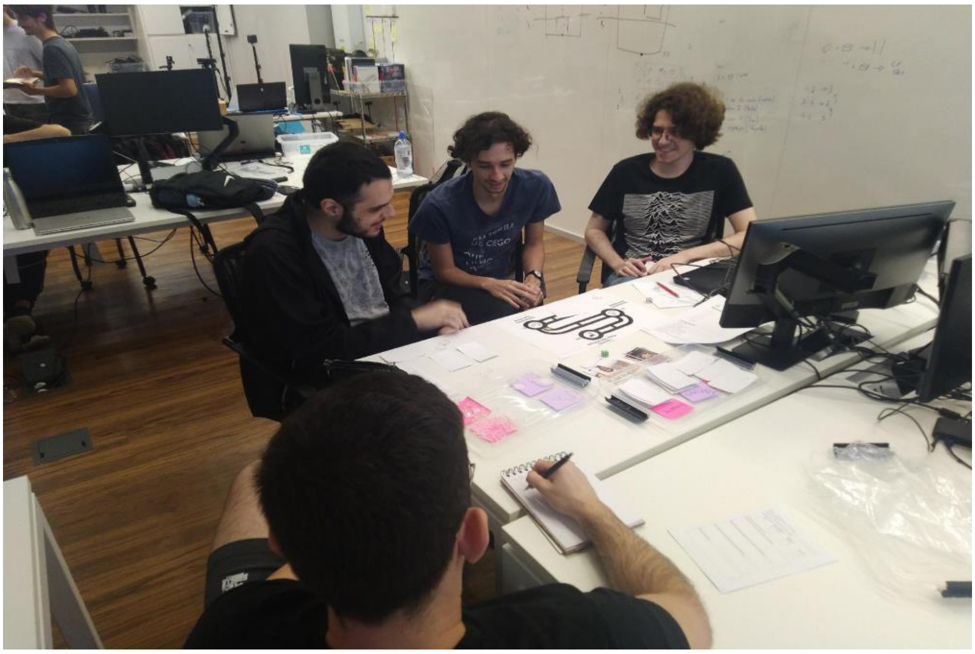

Figure 1. Peers testing a boardgame while one of the team takes note

3.2 Tutorial

At this point, it is introduced for the students the Unity game engine that will be used throughout the rest of the course. Unity is a 2D and 3D game engine platform widely used for game development, both in AAA games from large companies and teams, as well as in the indie scene composed of solo developers or small companies (Polfeldt, 2020). This engine was chosen for presenting a good learning curve, abundant material available on the internet, and a good balance between abstraction and code.

In order for the students to master the tool, it is proposed that they follow one of the official tutorials, which introduces the vast majority of the basic concepts that they will need to use, such as script creation, camera controls, among others. In addition to the tutorial, students are encouraged to be creative with their newly acquired skills and knowledge.

3.3 2D Project

At this point, it is expected that the student has basic knowledge of development with Unity. To design their games more comprehensively, the Design Document is introduced to the students. Students are encouraged to base their documentation on the Design Dynamics Experience framework proposed by Walk, Görlich, & Barrett (2017). Simply put, this proposal divides game production thinking into three categories, each with more specific subcategories, as seen in Figure 2.

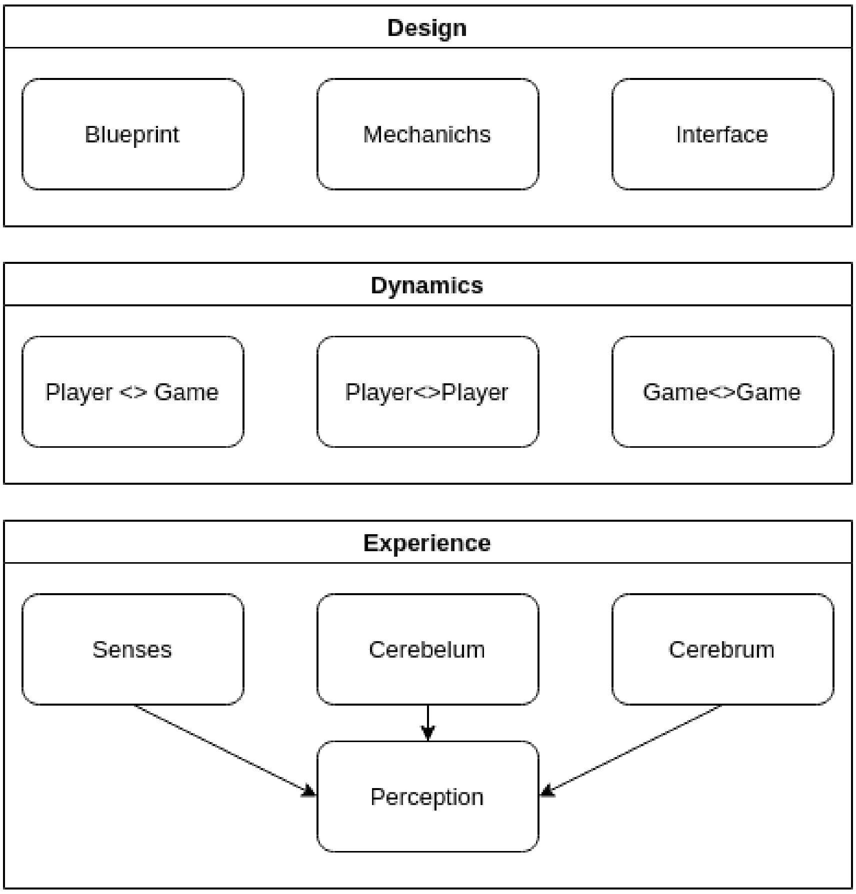

Figure 2. Simplified diagram of the DDE Framework (Walk, Görlich, & Barrett, 2017)

Each subcategory of DDE aims to draw attention to important aspects of building and developing a digital game. In Table 2, some guiding questions can be seen that seek to make the framework more tangible for students. Subcategories are used to construct the rubrics. This and the next project have a total of 12 rubrics listed: Blueprint, Mechanics, Interface, Dynamics, Flow, Experience, Replayability, Level Design, Composition, Game Balance, GDD, and Menus.

During the weekly monitoring of students' projects, professors understand that it is highly unlikely for all games proposed to fully meet all the established rubrics. Therefore, a system to evaluate and prioritize the rubrics was developed according to their relevance to the project's success. The students must select the two of the mentioned rubrics, on the first review of the project to have a doubled weight on the final evaluation, this way we can ensure that the most critical aspects of the game development process are given the utmost attention. In contrast, during the final review, the students collaborate with the professor to identify an additional two rubrics that will be excluded from the final evaluation. The decision to exclude these rubrics must be justified based on specific criteria. For instance, if a game lacks random elements, it may result in limited replayability, making it reasonable to disregard that particular rubric. This approach aims to provide students with greater flexibility and creative freedom in their game design, allowing them to focus on other essential aspects of their projects. This way, we can avoid penalizing a particular game style, while still maintaining a high level of evaluation and feedback on the final project. Through this process, we aim to encourage students to learn and grow from their mistakes, while still pushing them towards achieving their best possible outcomes. In order to determine the final grade for the assessment, the overall score is calculated by taking the average of all the rubrics that have been evaluated.

Table 2. DDE Subcategories guiding questions.

Category	Subcategories	Guiding Questions
Design	Blueprint	Where are your game settings? How does this world works? What style is you game presented?
	Mechanics	Game Code
	Interface	How the player perceives the needed information your game?
Dynamics	Player<>Game	How the player interacts with the game?
	Player<>Player	How the player interacts with another player?
	Game<>Game	How the game interacts with itself?
Experience	Senses	What senses you want to feel?
	Cerebellum	What emotions you want your player to have?
	Cerebrum	What challenges are you presenting to the player?
	Perception	Gameplay, fun, beauty

3.4 Final Project

For the final project, another challenge to the students was added: the game must be designed for mobile devices, in the case, Android devices since it is simpler to publish projects in the platform. This requirement introduced further challenges and complexities, such as optimizing game performance for mobile devices, adapting game interfaces and controls for touch screens, and addressing the unique characteristics of mobile devices compared to traditional gaming platforms, such as joysticks or keyboards.

In this way, students were encouraged to think about the specific demands of mobile game development and to explore new strategies and techniques to overcome them. This also required them to consider the differences in hardware specifications and screen sizes of various mobile devices, and to ensure that their games were compatible with a wide range of devices.

Overall, the inclusion of mobile game development in the curriculum provided an opportunity for students to expand their skills and knowledge in game development and to prepare them for the growing demand for mobile games in the gaming industry.

4 Discussion

In addition to equipping our students with technical proficiency in game development, we recognize the importance of fostering their understanding of the business aspects of the industry. Alongside the technical curriculum, we have incorporated discussions on monetization and marketing strategies to provide them with a comprehensive view of the game development landscape. By exposing students to these topics, we aim to prepare them for the reality that creating games entails more than just honing their creative and technical skills; it also involves making informed decisions regarding financial considerations.

For the culmination of the course, we require students to implement ads within their final game project. This requirement serves as a valuable opportunity for students to delve into the intricacies of revenue generation strategies. They are encouraged to explore diverse approaches, considering factors such as the type of ads to incorporate, their strategic placement, and the potential impact on the overall player experience. By engaging with these considerations, students gain a deeper appreciation for the multifaceted challenges inherent in developing games that are both commercially successful and artistically satisfying.

We firmly believe that by introducing students to these business-oriented discussions in their educational journey, we are equipping them with vital skills and insights that will prove invaluable in their future careers. By understanding the financial aspects of the industry and actively considering monetization and marketing strategies, our students are better prepared to navigate the dynamic landscape of software development.

5 Conclusion

The implementation of the methodology proposed in this paper, along with the continuous revisions made to the course, has resulted in a remarkable improvement in the level of student engagement, as evidenced by qualitative results. The findings indicate a notable increase in active participation, improved communication, and enhanced collaboration among students. It is important to note that quantitative assessment and further analysis will be explored in future works to provide a comprehensive evaluation of the methodology's impact on student outcomes. The engagement was enhanced not only during the initial ideation phase of the projects but also throughout the production and delivery stages. The frequent feedback and meticulous monitoring of the students' progress enabled us to comprehend the dynamics and interactions within the groups quickly and accurately, encouraging them towards more ambitious and intricate projects. The adoption of a more participatory approach to learning, where students are given more autonomy in the development of their projects, has fostered an environment that encourages creativity, innovation, and critical thinking. Consequently, this approach has not only motivated the students but also helped them develop a deeper investment in their work. Moreover, by challenging the students to work on more ambitious projects, they were compelled to step out of their comfort zones and take risks, leading to a more significant and impactful learning experience. The success of this methodology in promoting student engagement and encouraging the development of complex and innovative projects is evident.

It is also noteworthy that there has been a noticeable improvement in the quality of the projects developed by the students throughout the course. The students were given the freedom to develop their ideas and put into practice the skills they had acquired, resulting in a significant improvement in the final projects. The continuous revisions of the projects enabled the students to refine their techniques and enhance the quality of their outcomes. Therefore, we conclude that the digital games course, coupled with the proposed practices, offers an exceptional opportunity for students to improve their soft skills and develop several essential hard skills that are highly valuable for their future careers.

6 References

Beck, K., Beedle, M., van Bennekum, A., Cockburn, A., Cunningham, W., Fowler, M., . . . Thomas, D. (2001). Manifesto for Agile Software Development. Manifesto for Agile Software Development. Retrieved from http://www.agilemanifesto.org/

Cagiltay, N. E. (2007, May). Teaching software engineering by means of computer-game development: Challenges and opportunities. British Journal of Educational Technology, 38, 405–415. doi:10.1111/j.1467-8535.2007.00705.x

Duch, B. J., Allen, D., & Harold, B. (1997). Problem-based Learning: Preparing Students to Succeed in the 21st Century. Essays on Teaching Excellence.

Fernandes, S., Abelha, M., & Albuquerque, A. S. (2022). The student journey in PBL: using individual portfolios to promote self-reflection and assessment as learning. PAEE/ALE. doi:10.5281/ZENODO.7058095

Guimaraes, M., & Murray, M. (2008). An exploratory overview of teaching computer game development. Journal of Computing Sciences in Colleges.

Hattingh, T. S. (2022). Are your rubrics hitting the mark? An exploration of the use of rubrics for project-based learning in engineering. PAEE/ALE. doi:10.5281/ZENODO.7062090

S. Al-Ratrout. (2019). Impact of using Agile Methods in Software Engineering Education: A Case Study. 6th International Conference on Control, Decision and Information Technologies (CoDIT), (pp. 1986-1991). Paris, France. doi: 10.1109/CoDIT.2019.8820377

Salibi, J. G., Machado, B. A., Rodrigues, J. d., Souza, F. B., & Campos, R. d. (2021). The use of games in a graduation course in an engineering faculty. PAEE/ALE. doi:10.5281/ZENODO.5096805

Sreehari, D. P. (2021, July). Essential Soft Skills for Workplace Success. Revista Gestão Inovação e Tecnologias, 11, 2648–2654. doi:10.47059/revistageintec.v11i4.2306

Walk, W., Görlich, D., & Barrett, M. (2017). Design, Dynamics, Experience (DDE): An Advancement of the MDA Framework for Game Design. In Game Dynamics (pp. 27–45). Springer International Publishing. doi:10.1007/978-3-319-53088-8_3

Wu, B., & Wang, A. I. (2012). A Guideline for Game Development-Based Learning: A Literature Review. International Journal of Computer Games Technology, 2012, 1–20. doi:10.1155/2012/103710

Yousef, Y. A., Elzamly, A. M., Doheir, M., & Yaacob, N. M. (2022, December). Assessing Soft Skills for Software Requirements Engineering Processes. Journal of Computing and Information Technology, 29, 209–218. doi:10.20532/cit.2021.1005397

PAEE/ALE’2023 Full Papers – Students’ Award Submissions

Submissions accepted for the PAEE/ALE’2023 Students’ Award.

Sentiment analysis of comments made by students at the end of their internships using data mining

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Abstract

Nowadays, sentiment analysis techniques are widely used in companies to know what customers feel about the products or services they offer. In the academic field these techniques are also used to know the opinions of the actors in the teaching-learning process, which can be students, teachers or different organizations with which they are linked. The objective of the present study is to know the opinions that students have at the end of their professional internship in the companies. For this purpose, a descriptive, correlational and longitudinal research was carried out. An exploratory instrument was applied to all students of the different careers of the Faculty of Chemical Engineering, of the Autonomous University of Yucatan in Mexico at the end of their internship in the company in three different periods from 2016 to 2022. The results show that more than 90% of the students expressed positive feelings towards the internship, as well as the activities or projects developed during their stay in the company. In conclusion, some of the comments expressed by the students reinforce the importance of being able to acquire work experience in real learning environments and increase their professional growth, as well as the acquisition of new knowledge and skills.

Keywords: Sentiment Analysis; Internship; Real-World Environments; Work Experience; Text Mining.

1 Introduction

In 2012, the Universidad Autónoma de Yucatán (UADY) modified its educational model and created the Modelo de Enseñanza para la Formación Integral (MEFI) where it states that: students must carry out internships in real learning environments called Professional Practices of at least 160 hours, to apply the competencies stated in the curricula (UADY, 2012), as well as acquire new skills that organizations demand today, such as soft skills. In the Faculty of Chemical Engineering (FIQ) of the UADY there are five bachelor's degrees: Industrial Chemical Engineering, Industrial Logistics Engineering, Food Engineering, Biotechnology Engineering and Applied Chemistry, which declare in their curricula the semester in which the internship should be performed and it is generally in the last semesters depending on the degree in question. This course is mandatory and its location in the curriculum allows students to have the necessary time to join a company in which they must accumulate 480 hours as interns, in addition to the other requirements for its approval.

The School of Chemical Engineering justifies the internship within the educational program as a guided and supervised exercise, in which students are allowed to use the competencies they have developed and/or develop new ones associated with the graduate profile as professional skills through participation in the development of projects that contribute to the detection and solution of specific problems of the company, providing work experience to future graduates to increase their competitiveness and thus promote their integration into the labor field (FIQ, 2014a). It is important to highlight that the location of the subject in the curricula represents a competitive advantage and at the same time an opportunity for the above.

Table 1 shows the location of the course in the curriculum, by program, credits and the number of hours to be performed in the company.

Table 1. Location of the internship in each program planning sheet.

Undergraduate Program	Name of the course	Semester in the planning sheet	Credits	# of hours at the company
Industrial Chemistry (QI)	Práctica Profesional	10	12	480
Applied Chemistry (QA)	Práctica Profesional	10	12	400
Biotechnology Engineering (IB)	Práctica Profesional	10	12	480
Food Engineering (IA)	Práctica Profesional	10	12	480
Industrial Chemistry Engineering (IQI)	Práctica Profesional	9	12	480
Logistic Industrial Engineering (IIL)	Práctica Profesional I	9	12	480
	Práctica Profesional II	10	12	480

The internship course is supervised by a professor throughout the semester, who is responsible for documenting the process through a series of activities to be carried out by the student and the person designated as supervisor by the company (Figure 1).

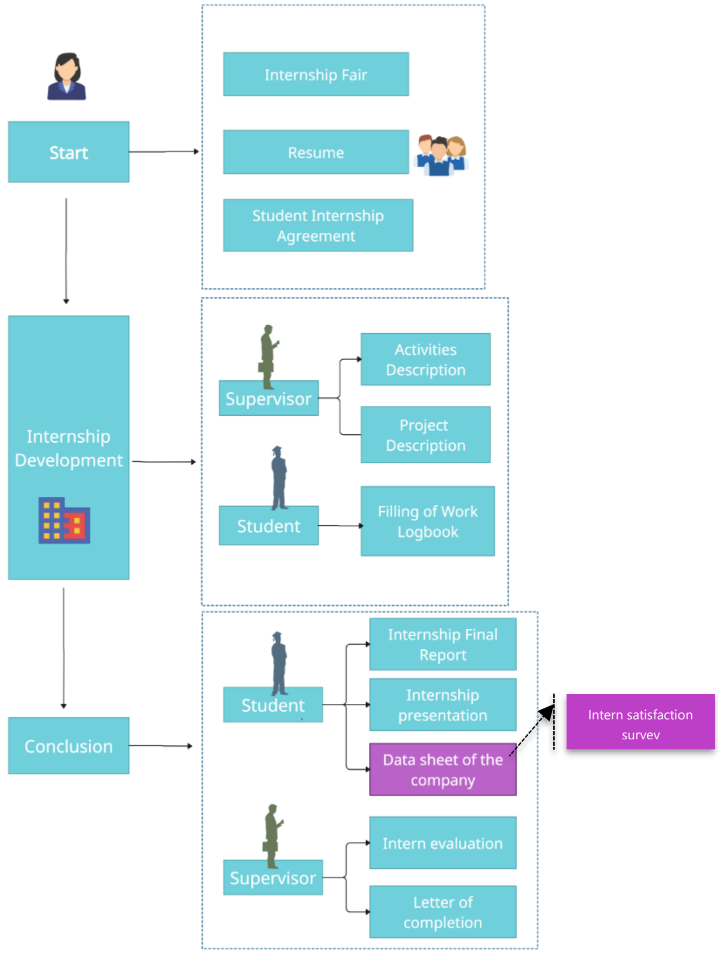

Figure 1. The Internship process.

The general guidelines for the operation of educational programs at UADY, the Educational Model for Integral Formation (MEFI, 2012) defines that professional internships must be carried out outside the Faculty and in one of the declared periods of the school calendar, which are: August-December, January-May and summer.

Once the students have concluded their stay in the company, a form is applied to them that collects information related to their stay, which is divided into three sections: the first requests general information about the company, the internship and the student with emphasis on their satisfaction during their internship; the second is focused on whether there are graduates of the Faculty hired in the company, and the third section focuses on job placement by asking whether the student received any job offer from the company.

1.1 Problem Definition

The Faculty of Chemical Engineering of the UADY has kept track of all students who perform professional internships since the creation of its study programs. In 2012, the process was systematized and was defined as shown in Figure 1. That same year, a pilot instrument began to be applied to collect information on internships, but it was only applied to one study program. For 2014 this instrument was enriched with additional information to know the satisfaction of the students (interns), however, the items for the collection of comments were not mandatory.

Since 2016, with the growth of enrollment at FIQ and the creation of two new bachelor's degrees, this instrument was modified and validated with the group of professors who teach the course in order to apply it in all programs and be able to have accurate information from the companies and students. With the data obtained, it is possible to know the satisfaction of the students at the end of their stay in the selected companies using sentiment analysis tools. The data collected in this research was from 2016 to 2022.

1.2 Sentiment analysis

Sentiment analysis is a powerful tool that helps companies understand customer feelings. It is used to mine text data from various sources, such as blogs, support forums, and social media, to extract customers' opinions and attitudes (Hossain, 2022). A sentiment analysis algorithm categorizes the polarity of a text as either positive, negative, or neutral. Sentiment analysis is used to make important assessments of a customer's attitude toward a company but it could also be used in other fields, such as education, to learn about students´ emotions in many activities related to the process of teaching-and-learning. It can be applied at three levels: sentence level, document level, and aspect level. Deep learning algorithms, machine learning models, and recurrent neural networks are prevalent in sentiment and emotion analysis (Nandwani & Verma, 2021).

Data mining research of the teaching and learning process has grown into various areas and themes, and its review provided perspectives, identified trends and observed potential research directions. The SocialMining model uses a corpus of real comments in Spanish about teacher performance assessment (Tubishat, Abushariah, & Idris 2019).). New methods are constantly being proposed in order to improve sentiment analysis accuracy and efficiency.

Natural language processing (NLP) is an interdisciplinary methodology that focuses on the interactions between computers and human language. The field combines knowledge from computer science, artificial intelligence and linguistics to design mechanisms that enable effective communication through programs that execute or simulate such communication. Instead of approaching natural language communication in an abstract way, NLP seeks to create concrete and practical solutions that can be implemented using a computer language (Franco, Martínez, & Domínguez, 2021). In 2022, an opinion survey was applied to 832 students of the Faculty of Social Communication of the Central University of Ecuador to analyze the perception of students on the application of institutional regulations for distance learning in Ecuador using natural language processing and opinion mining to determine the sentiment expressed in students' texts in the university domain, with the support of the Python programming language (Herrera & Benavides, 2022).

Another study conducted by (Golondrino, Londoño, & Martínez, 2021), during a "Business Entrepreneurship" course of the Chemical Engineering Program of the University of Cartagena, used sentiment and text analysis tools to evaluate the satisfaction of the attendees during a virtual fair, evaluating the different opinions of the evaluators using Python and the library provided by the paralleldots service.

1.3 Objective

The aim of the present study is to catalogue the satisfaction of the students through the comments emitted at the end of their internships in the companies, applying sentiment analysis tools.

2 Scope or Metodology

A descriptive, correlational and longitudinal investigation (Hernandez, 2004) was carried out. An exploratory instrument was applied through the Google forms® tool via the Internet to all students enrolled in the course at the end of their internship. This was carried out during the academic year in three different periods (August-December, January-May and summer) from 2016 to 2022.

It should be noted that the focus of this research is the analysis of the item "additional comments about your experience" of the survey applied, which will be available until July 2023 at the following link https://forms.gle/rr3h2M498KSsdd6V6.

2.1 Consolidation of Excel files

To begin the analysis, the survey results were downloaded in Microsoft® Excel format to unify a total of 22 files corresponding to the years 2014 to 2022. Subsequently, the surveys for the years 2014 and 2015 were discarded because they did not contain complete information on the item to be evaluated due to the fact that their capture was not marked as mandatory.

2.2 Data cleaning

Using the Python® programming language, we proceeded to clean the data, eliminating null or empty data, as well as atypical data in any cell of the file in question in order to keep as much reliable data as possible for the analysis. Similarly, the same operation was performed with duplicate data.

2.3 Sentiment analysis

For the sentiment analysis, a pre-treatment of the data was performed, highlighting the fact that only the column containing the students' comments was used, so all the data was eliminated. Subsequently, we proceeded to normalize the data to avoid the loss of the polarity of the sentiment by means of the function "=MINUSC()" in Microsoft® Excel, likewise we eliminated invalid characters for the analysis such as the symbol 😊, XD, :D and the quotation marks "".

This process resulted in the generation of two new files, one comma separated (csv) and the other in text (txt), which were used for the sentiment analysis of the comments with a total of 1520 records. A previous analysis was carried out with the Python® programming language, using the Pandas and NTLK (Natural Language Toolkit) libraries.

- Pandas is a Python library specialized in the analysis and management of data structures. This library focuses on the definition of new data structures and facilitates the reading and writing of files in various formats, such as CSV, Excel and SQL databases. It also provides methods for accessing and manipulating data using indexes or row and column names, reorganizing, splitting and combining data sets, working with time series and performing all these operations with high efficiency.

- NTLK is a Python programming platform that focuses on natural language processing. It stands out for its ease of use, offering more than 50 corpora and lexical resources, as well as several text processing libraries for classification, tokenization, word reduction, tagging, parsing and semantic reasoning. It also provides wrappers for high-quality natural language processing libraries and an active discussion forum.

This library classifies the analyzed texts into three categories, Positive, Negative and Neutral. The classification is attributed to the percentage obtained during the execution of the algorithm. A percentage greater than zero is considered as a positive comment, equal to zero as neutral and finally less than zero as negative, (Figure 2).

	A	B	C	D	E	F
1		**Comentarios adicionales**	**entimie**	**Positivo**	**Neutral**	**Negativc**
2	**0**	me agrado los procesos que se maneja en esta empresa	0	FALSO	VERDADERO	FALSO
3	**1**	excelente empresa	0	FALSO	VERDADERO	FALSO
4	**2**	ninguno	0	FALSO	VERDADERO	FALSO
5	**3**	aprendía muchísimo en el área en el que estuve trabaja	0	FALSO	VERDADERO	FALSO
6	**9**	buena empresa, con buena administración y desarrollo	-0.5574	FALSO	FALSO	VERDADERO
7	**11**	me sirvio de mucho, mi estancia como practicante en es	-0.5267	FALSO	FALSO	VERDADERO
8	**13**	es una segunda escuela, pude aplicar mucho de lo que	0	FALSO	VERDADERO	FALSO
9	**14**	la empresa me brinda las oportunidades para desarrolla	0	FALSO	VERDADERO	FALSO
10	**16**	me siento muy contenta de haber formado parte de la e	0	FALSO	VERDADERO	FALSO
11	**17**	el puesto debe dirigirse hacia el perfil administrativo n	-0.296	FALSO	FALSO	VERDADERO
12	**37**	una buena empresa donde estoy realizando mis práctic	0	FALSO	VERDADERO	FALSO
13	**40**	es una excelente empresa para desarrollar mis habilida	0	FALSO	VERDADERO	FALSO
14	**41**	me encuentro muy agradecido con la empresa que me l	0	FALSO	VERDADERO	FALSO
15	**44**	un buen lugar para trabajar.	0	FALSO	VERDADERO	FALSO
16	**45**	excelente empresa, en donde el ambiente laboral es cc	0	FALSO	VERDADERO	FALSO
17	**49**	pcc es una empresa la cual hay mucha area de oportuni	0	FALSO	VERDADERO	FALSO
18	**51**	me contrataron para monitoreo de camiones, he desarr	0	FALSO	VERDADERO	FALSO
19	**53**	esta empresa brinda oportunidades de crecimiento a pı	-0.5574	FALSO	FALSO	VERDADERO
20	**58**	muy buen trato por parte del el jefe de departamento,	-0.8481	FALSO	FALSO	VERDADERO
21	**63**	muy buena empresa, mas grande de lo esperado. ojala	0	FALSO	VERDADERO	FALSO
22	**69**	una experiencia muy diferente comparada con las de m	0	FALSO	VERDADERO	FALSO

Figure 2. Classification of some comments using *ntlk* in phyton.

At first glance, the results obtained in this pre-analysis, it was considered that they are not congruent with what was expressed by the students because when reading the comments, it can be observed that the grade given differs in the value given to the polarity of the comment, which could be due to the language in which the comments are generated.

Therefore, this analysis was discarded and an API (Application programming interfaces) of the MeaningCloud® platform called Text-Analytics-for-Excel was installed, which offers different text analytics functionalities. The analysis tools enabled by the API are classify text, analyze sentiment, identify language, extract topics, categorize texts, cluster texts (Figure 3).

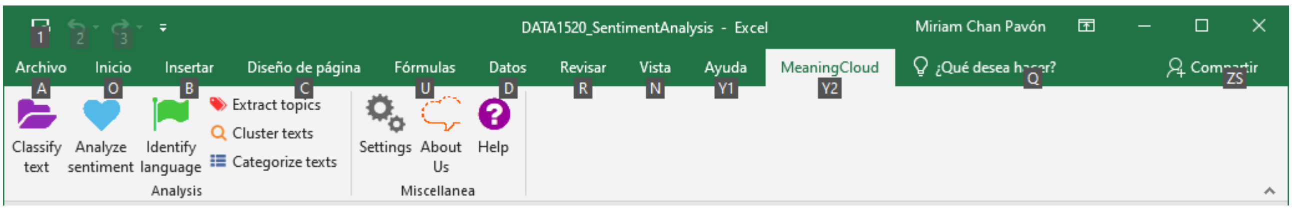

Figure 3. Meaningcloud® API Tools.

For the sentiment analysis of the 1520 records, the Spanish language and the general analysis model provided by the tool were selected, and the results generated by the tool are based on the following concepts described in Table 2.

Table 2. Meaningcloud sentiment analysis results.

polarity (score_tag)	Polarity of the element it refers to: global polarity, polarity_term, sentimented_concept, sentimented_entity, segment or sentence. Possible values: P+: strong positive P: positive NEU: neutral N: negative N+: strong negative NONE: without polarity
agreement	Marks the agreement between the sentiments detected in the text, the sentence or the segment it refers to. It has two possible values: AGREEMENT: the different elements have the same polarity. DISAGREEMENT: there is disagreement between the different elements' polarity.
subjectivity	Marks the subjectivity of the text. It has two possible values: OBJECTIVE : the text does not have any subjectivity marks. SUBJECTIVE : the text has subjective marks.
confidence	Represents the confidence associated with the sentiment analysis performed on the text. Its value is an integer number in the 0-100 range.
irony	Indicates the irony of the text. It has two possible values: NONIRONIC: the text does not have any irony marks. IRONIC: the text has irony marks

3 Results

The population consisted of 1520 students from the following undergraduate programs: Industrial Chemistry (QI), Applied Chemistry (QA), Industrial Chemical Engineering (IQI), Industrial Logistics Engineering (IIL), Food Engineering (IA) and Biotechnology Engineering (IB). The number of students by degree and gender is described (Figure 4).

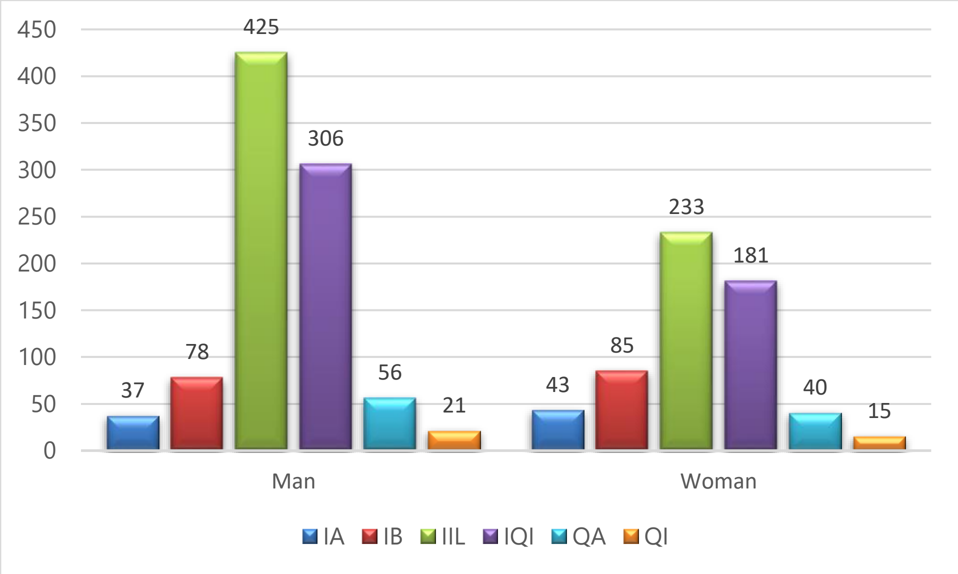

Figure 4. Distribution of population of students by sex and program.

Table 3 describes another important characteristic of the companies where the students carried out their internships, which is their size. It was found that 41.63% of the total number of companies is large according to the number of employees. On the other hand, 19.99% of the students of the Industrial Logistics Engineering degree program did their internships in these companies compared to those of Food Engineering with 1.46%, being this degree the one with less presence in these companies since the Industrial Chemistry degree program was modified and changed its name to Applied Chemistry, and between the two they represent 2.19%. As for the companies, industrial companies represented 51.20%, services 26.16% and commercial 17.60%; those with the lowest percentage were education and/or research, social and public, totaling 2.19%. The above results reinforce what is stated in the new educational model regarding the insertion of students in real learning environments related to the areas of impact of their graduate profile (Figure 5 and the new cloud).

Table 3. Descriptive statistics of enterprises by program.

	Program						
Enterprise Size	**IA**	**IB**	**IIL**	**IQI**	**QA**	**QI**	**Total**
Big	1.46%	3.19%	19.99%	14.81%	1.86%	0.33%	41.63%
Medium	1.66%	1.73%	11.35%	9.23%	1.86%	0.66%	26.49%
Micro	0.80%	2.52%	4.12%	3.12%	1.06%	0.46%	12.08%
Small	1.26%	3.25%	8.10%	5.05%	1.46%	0.66%	19.79%
Total	**5.18%**	**10.69%**	**43.56%**	**32.20%**	**6.24%**	**2.12%**	**100.00%**

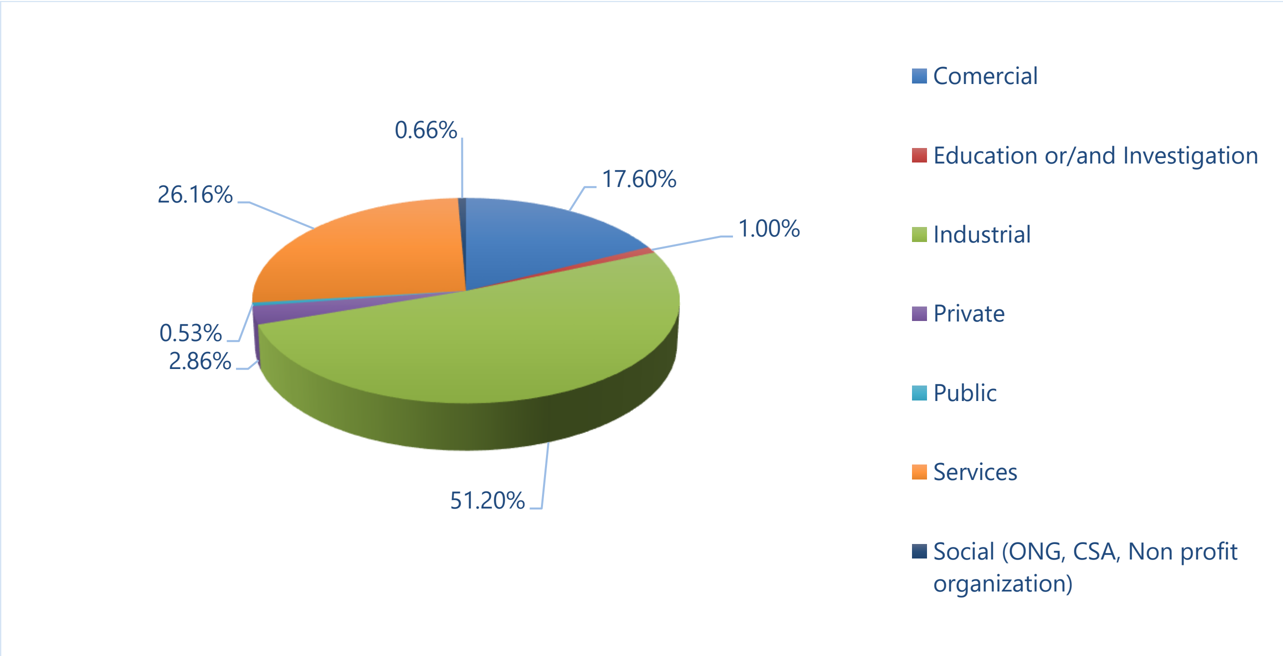

Figure 5. Enterprise classification.

A word count was performed using a cloud plotter to have a visual image of the most frequently expressed feelings without eliminating the stopwords (Figure 6), and then the results were plotted (Figure 7) obtained from the analysis performed in Excel with the MeaningCloud API, which shows how the polarity P (positive) and P+ (very positive) represent 73.95% of the total data, obtaining 725 and 399 responses respectively. 95% of the total data obtaining 725 and 399 responses respectively and the lowest number with polarity N- (very negative) with 8 responses representing 0.53%, the percentages of all polarities are shown in Table 4.

Figure 6. Wordcloud from the student´s opinion.

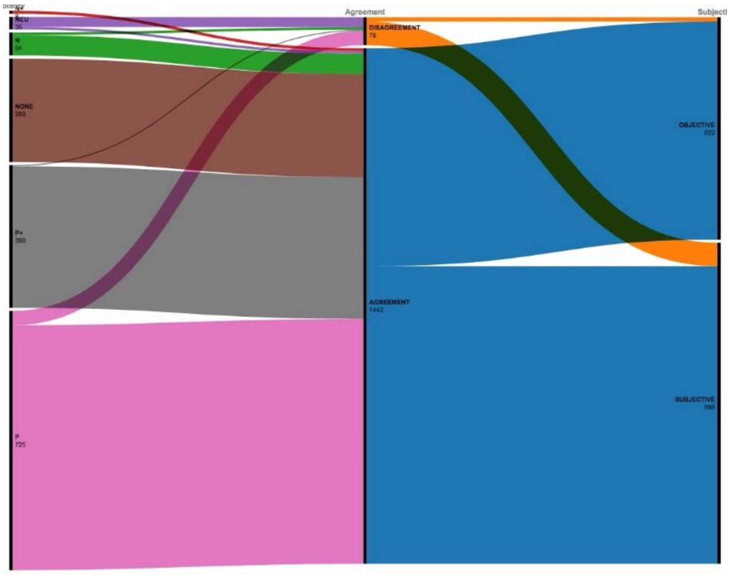

Figure 7. Sentiment analysis results totals.

Table 4. Sentiment Análisis results percentage.

Polarity	Percentage
N	4.21%
N+	0.53%
NEU	2.30%
NONE	19.01%
P	47.70%
P+	26.25%
Total general	**100.00%**

Table 5 shows the results obtained, highlighting that the tool gives a result of *Agreement* if all the words in the text or sentence evaluated are positive and, on the contrary, it assigns *Disagreement* if there are both positive and negative words, which means that the expression evaluated has clear-obscures, which can be seen more clearly with very negative polarities (N+).

Table 5. Sentiment analysis results summarize by polarity and agreement.

POLARITY	AGREEMENT	DISAGREEMENT	TOTAL GRAL.
N	**57**	**7**	**64**
NONIRONIC	**57**	**7**	**64**
OBJECTIVE	21	3	24
SUBJECTIVE	36	4	40
N+	**8**		**8**
NONIRONIC	**8**		**8**
OBJECTIVE	6		6
SUBJECTIVE	2		2
NEU	**7**	**28**	**35**
IRONIC		**1**	**1**

SUBJECTIVE		1	1
NONIRONIC	**7**	**27**	**34**
OBJECTIVE	5	6	11
SUBJECTIVE	2	21	23
NONE	**289**		**289**
NONIRONIC	**289**		**289**
OBJECTIVE	281		281
SUBJECTIVE	8		8
P	**685**	**40**	**725**
NONIRONIC	**685**	**40**	**725**
OBJECTIVE	235	3	238
SUBJECTIVE	450	37	487
P+	**396**	**3**	**399**
NONIRONIC	**396**	**3**	**399**
OBJECTIVE	62		62
SUBJECTIVE	334	3	337
TOTAL GRAL.	**1442**	**78**	**1520**

The tool also presents additional information in the results generated at the end of the analysis, such as reliability, subjectivity and irony; Table 6 shows an example of some of the results. The aforementioned data were not considered for the analysis of results, since the objective of the research is to know the polarity of the feeling expressed by the student.

Figure 8 shows a comparison of the areas where students carried out their internships within the company and what is stated in the graduation profile of each degree, which shows that there is a correlation that may influence the comments that students made in the survey.

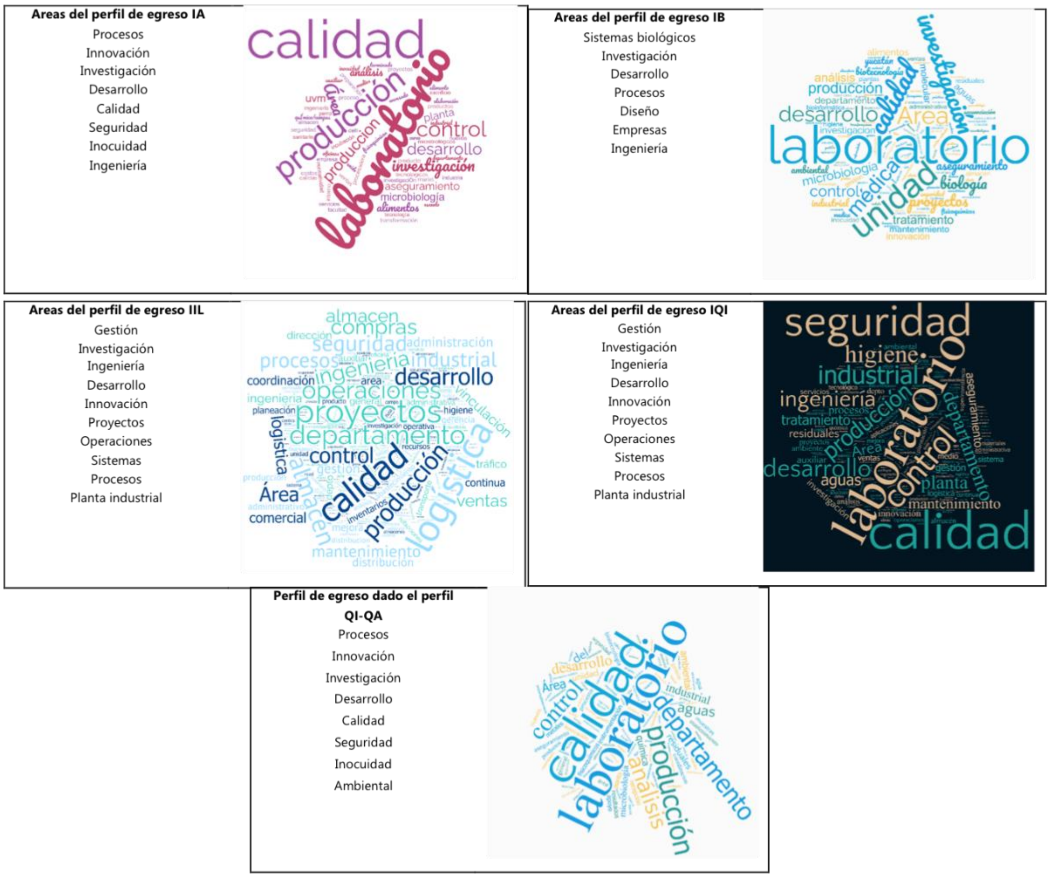

Figure 8. Areas of impact of the graduate Vs. areas where they performed their internships in the company.

Table 6. Example of some results of text analysis applied to student comments..

Text	Polarity	Agreement	Subjectivity	Confidence	Irony
el ambiente de trabajo no es el idóneo para unas prácticas profesionales existen muchos conflictos organizacionales del manejo del personal y de la rotación de los mismos en lo personal no sería un lugar que recomendaría	N	AGREEMENT	SUBJECTIVE	92	NONIRONIC
la fecha de término aún no la defino porque la práctica la estoy haciendo por proyecto puse una fecha de término x para poder mandar el formulario	N	AGREEMENT	OBJECTIVE	97	NONIRONIC
muy pocas actividades asignadas por el jefe inmediato	N+	AGREEMENT	OBJECTIVE	100	NONIRONIC
muy poca cultura organizacional	N+	AGREEMENT	OBJECTIVE	100	NONIRONIC
ninguno	NONE	AGREEMENT	OBJECTIVE	100	NONIRONIC
el puesto debe dirigirse hacia el perfil administrativo no ingenieril	NONE	AGREEMENT	OBJECTIVE	100	NONIRONIC
estoy muy feliz con la oportunidad aprendí demasiado y el ambiente laboral es fascinante	NEU	DISAGREEMENT	SUBJECTIVE	82	IRONIC
soy alumno de movilidad perteneciente al ipn en mi escuela de origen las prácticas duran un tercio de tiempo de las cursadas aquí en la facultad sin embargo da la oportunidad que el alumno tenga mayor acercamiento al sector empresarial lamento profundamente que estas tuvieran que interrumpirse por la contingencia del covid19	NEU	AGREEMENT	OBJECTIVE	100	NONIRONIC
fue una experiencia grata y de gran utilidad para mi formación profesional	P	AGREEMENT	SUBJECTIVE	100	NONIRONIC
buena experiencia	P	AGREEMENT	OBJECTIVE	100	NONIRONIC
es una gran empresa que pone en reto tus habilidades teóricas adquiridas durante la carrera	P+	AGREEMENT	OBJECTIVE	98	NONIRONIC
el conocimiento que adquirí es enriquecedor para mi perfil profesional y con ello tener un respaldo de experiencia en el ámbito laboral	P+	AGREEMENT	SUBJECTIVE	100	NONIRONIC
fue una excelente manera de adquirir conocimientos sobre el trabajo en la industria y sobre relacionarse con el entorno de trabajo	P+	AGREEMENT	SUBJECTIVE	100	NONIRONIC

4 Conclusion

In conclusion, it can be affirmed that the satisfaction that the students expressed at the end of their stay in the company was good since most of them had a POSITIVE and VERY POSITIVE polarity; however, the traditional text analysis tools still present problems in semantics; proof of this are the results obtained in the neutral comments that contain words that should be qualified with a positive polarity and something similar happens in the comments qualified as negative that do not contain words recognized as positive. Therefore, it is recommended to use artificial intelligence tools such as ChatGPT, which can be more efficient given the processing algorithm it uses. The instrument used provides more information that will be used in future work to find patterns and correlations between the polarity of the feelings found and factors such as the economic support received during the internship, the area within the company where the internship was performed or the work proposals at the end of the stay, so it is recommended to continue with the analysis of the information with data analytics tools so that the academic authorities can make decisions about updating the curricula.

5 References

Facultad de Ingeniería Química (FIQ) (2014a). Propuesta de Modificación del Plan de Estudios de la Licenciatura en Ingeniería Industrial Logística. Yucatán, México: UADY.

Franco, E., Martínez, R. A., & Domínguez, V. (2021). Modelos predictivos de riesgo académico en carreras de computación con minería de datos educativos. Revista de Educación a Distancia, 21(66). https://doi.org/10.6018/red.463561

Golondrino, G. E., Londoño, C. P., & Martínez, L. M. (2021). Análisis de sentimientos sobre la percepción de los participantes de una feria virtual de emprendimiento durante el confinamiento. Investigación e innovación en ingenierías, 9(3), 32-45. https://doi.org/10.17081/invinno.9.3.5316

Herrera-Flores, B., & Benavides-Morales, C. (2022). Minería de opiniones en un modelo de educación remota de emergencia en el Ecuador. South Florida Journal of Development, 3(4), 4582-4598. https://doi.org/10.46932/sfjdv3n4-037

Hossain, M.S., Rahman, M.F., Uddin, M.K. and Hossain, M.K. (2022), "Customer sentiment analysis and prediction of halal restaurants using machine learning approaches", Journal of Islamic Marketing, Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/JIMA-04-2021-0125

Meaningclouds (2023, marzo 30). *Analítica de texto*. https://www.meaningcloud.com/es/soluciones/analitica-de-texto

Nandwani, P., & Verma, R. (2021). A review on sentiment analysis and emotion detection from text. Soc. Netw. Anal. Min. 11, 81. https://doi.org/10.1007/s13278-021-00776-6

Tubishat, M., Abushariah, M.A., & Idris, N. (2019). Improved whale optimization algorithm for feature selection in Arabic sentiment analysis. Appl Intell 49, 1688–1707. https://doi.org/10.1007/s10489-018-1334-8

Universidad Autónoma de Yucatán (UADY) (2012). *Modelo Educativo para la Formación Integral (MEFI)*. México: UADY.

Universidad Autónoma de Yucatán (UADY) (9 de enero de 2023). *Plan de estudios de la licenciatura en Ingeniería en Alimentos de la Facultad de Ingeniería Química*. https://www.ingquimica.uady.mx/ia/malla2017.php

Universidad Autónoma de Yucatán (9 de enero de 2023). *Plan de estudios de la licenciatura en Ingeniería en Biotecnología de la Facultad de Ingeniería Química*. https://www.ingquimica.uady.mx/ib/malla.php

Universidad Autónoma de Yucatán (9 de enero de 2023). *Plan de estudios de la licenciatura en Ingeniería Industrial Logística de la Facultad de Ingeniería Química*. https://www.ingquimica.uady.mx/iil/malla.php

Universidad Autónoma de Yucatán (9 de enero de 2023). *Plan de estudios de la licenciatura en Ingeniería Química Industrial de la Facultad de Ingeniería Química*. https://www.ingquimica.uady.mx/iil/malla.php

Universidad Autónoma de Yucatán (9 de enero de 2023). *Plan de estudios de la licenciatura en Química Aplicada de la Facultad de Ingeniería Química*. https://www.quimicaaplicada.uady.mx/

Perception of students and teachers about the skills trained in curriculum projects at an engineering school

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Abstract

Based on the National Engineering Curriculum Guidelines (DCN), technical and transversal skills were proposed for Special Projects and Activities (PAEs) in the first half of 2022, which directly influence the curriculum of Engineering, Design, Administration, Information Systems and Computer Science students at the Mauá Institute of Technology. Participant students and teachers offered data based on their experiences, which was used to measure the results of this new approach. This article analyses the level of compatibility between educators' expectations and students' perceptions regarding the scope and effectiveness of these competencies. Percentage analysis was used, based on the raw data. We found that the student-teacher perceptions were aligned in most cases, symbolizing the effectiveness of the proposal.

Keywords: Teaching by Skills. Special Projects and Activities. DCN. Engineering Education. Engineering Curriculum.

1 Introduction

The National Curricular Guidelines for Engineering programs (DCN) (BRAZIL, 1996) were analysed and revised in a report homologated in January 2019. The soft skills are referred to in Article 3, while the technical competencies are related to Article 4 of these guidelines. This report gave rise to a resolution project that addresses the necessary understandings for an undergraduate student in Engineering. Palú, Mattasoglio Neto & Matta (2022) proposed as a method of assessing learning in Projects and Special Activities (PAEs) in Engineering Courses, 20 segmentations of evaluative competencies that seek to contribute to the understanding of how students develop and learn in this type of proposal. The PAEs project, within the Mauá Institute of Technology (IMT), is the operationalization strategy of the National Curricular Guidelines for Engineering (DCN) (BRAZIL, 2004; 2019; 2020), aiming to foster the development of general competencies of engineer training through projects and curricular activities. The PAEs are offered with a minimum of 160 hours of training in all academic years, except for the final year of the course. These competencies were divided into technical competencies and soft skills. The first category encompasses PAEs that are linked to technical concepts aimed at the development of hard skills. The soft skills, on the other hand, transcend the disciplines regularly addressed, that is, they are not tied to content or courses - they are actually directed towards proposing interdisciplinary projects, with a focus on the student's development as an individual, also known as soft skills. This article presents the results of this classification, verifying its effectiveness as a tool for maximizing student achievement.

2 Methodology

The methodology used involves comparing the students' interpretation with the disciplinary objectives of the teachers, which is important in determining whether this evaluative criteria scale is functional or if other methods should be proposed.

2.1 Study context

According to Sesoko (2014), Trans.

> "Problem Based Learning (PBL) is a collaborative, constructivist, and contextualized methodology that uses problems to initiate, guide, and motivate the learning of concepts, theories, and the development of transversal skills such as leadership, effective communication, teamwork, project management, and proactivity. In this methodology, a sequence of problematic situations is proposed to students without the necessary knowledge for their resolution being previously taught by the teacher. The problem can be real or fictional, should have an open solution, may contain multiple solutions, and may involve contradictory objectives and/or complex boundary conditions that force students to make technical considerations in order to solve the problem. The main objective is not the concepts used during the resolution process, but the decisions, considerations, and questions adopted to arrive at the final solution."

The competencies proposed by Palú, Mattasoglio Neto & Matta (2022) have a deep relationship with the National Curricular Guidelines for Engineering (DCNs) and the step of the Problem Based Learning approach. PBL offers a new perspective on understanding and evaluating the competencies focused on the DCNs for engineering. In this sense, problem-focused learning operationalizes the skills learned previously in the classroom and provides teachers with the opportunity to observe the development of students according to the competency-objectives in real-time, rather than after the fact. Transversal skills are strongly observed in this case, considering the decisions made by students and their impact on the team involved. Did the student demonstrate proactivity in proposing solutions? The technical concepts learned in class will subsequently be addressed by the technical competencies: Did the student use the concepts optimally?

These competencies are interrelated, demonstrating the intersection between the DCNs, the steps of PBL, and the competencies of the PAEs.

2.2 Data collection and Analysis

The data collection was carried out with by individually filled forms by teachers and students through Google Forms. From these forms, spreadsheets were organized with the raw data collected. The students were invited and informed about the forms at the end of the academic semester, and for students who attended in 2020, the form filling was voluntary. However, the teachers were required to fill out the forms. Student form questions are the following:

- Select the PAE (activity name)
- How was this PAE implemented? (remote/ in person)
- Select the PAE Supervisor (educator name)
- Which instruments were used to evaluate the activity?
- Select up to 3 items that you believe were developed in this activity. (Competencies developed)
- Select up to 3 competencies that you believe were developed in this activity. (Competencies developed)

Educator form questions:

- Select the name of your PAE (activity name).
- Choose the category of your PAE.
- Transversal competencies. (Competencies developed)
- Competencies developed in the PAE. (Competencies developed)
- Name(s) of the facilitator(s).
- How do you intend for your PAE to be implemented? (remote/ in person)

Based on this data collection methodology, despite the total population of IMT students being 2025, only 986 student responses were obtained, while from teachers, 174 projects were offered after analysis and student enrollment. The grouping criterion for the responses used was proposed by Palú, Mattasoglio Neto & Matta (2022).

Since the data was analyzed in percentages, statistical inference was used as the method to calculate the confidence interval, due to the qualitative nature of the variables (DEVORE, 2006). The confidence interval equation for proportions (1) was applied to calculate the margin of error based on each percentage. A CI of 95% was adopted.

Equation 1 – Confidence level equation for proportions (p' - sample proportion n - sample size z - number from the normal distribution table)

$$IC(p) = p' \pm z\sqrt{\frac{p'(1-p')}{n}} \quad (1)$$

The first step involved tallying the responses from the forms for each competency. Subsequently, these data were compiled and inserted into bar charts with raw numbers. The second step was refining the visualization to facilitate reader comprehension and analysis, by creating percentage-based charts based on the previous ones. Finally, in order to provide an overall picture, a chart was constructed correlating the percentages between the responses from students and teachers. This way, the data collection was organized based on the absolute data from the questionnaires and presented in percentage-based charts, facilitating statistical analysis and presentation of the results.

3 Results and Discussion

Out of a total of 174 Projects and Special Activities, 92 of them had at least one form response. From these 92 responses, a total of 2866 votes on competencies were recorded, as students could vote for more than one competency per project. For the analysis of technical and transversal competencies, the responses of students were analyzed first, followed by those of teachers, and finally a percentage comparison was conducted between the two, generating hypotheses from the data.

The data presented in all analyses refer to the PAEs offered in the first semester of 2022 and will be presented in figures based on the competencies proposed by Palú, Mattasoglio Neto, Matta (2022), as shown in Table 1 below.

Table 1 – Transversal Competencies

I	Critical Sense (Be Critical)
II	Information Selection (Be Selective)
III	Knowing how to face challenges
IV	Proactivity (Initiative)
V	Create / Innovate
VI	Organization / Planning
VII	Interpersonal relationship
VIII	Ability to deal with the unforeseen / Working in uncertain environments
IX	Ability to solve problems
X	Make decisions

Table 2 – Technical Competencies

I	To formulate and design desirable and innovative solutions in your area.
II	To analyze and understand the phenomena, events and models in your area based on the sciences that underlie it.
III	Creatively conceive, design and analyze systems, products (goods and services), components or processes, technically and economically viable.
IV	Implement, oversee and control solutions in your area.
V	Communicate effectively in written, oral and graphic forms, including communication in LIBRAS.
VI	Working and leading multidisciplinary teams
VII	Know and ethically apply the legislation and normative acts within the scope of the exercise of the profession.
VIII	Learn autonomously and deal with new and/or complex situations and contexts.
IX	Understand the potential of technologies and apply them in solving problems and taking advantage of opportunities.
X	Get to know the productive sector of your specialization, revealing a solid sectorial view, related to the market, materials, production processes and Technologies.

In the analysis of data on transversal and technical competencies, we will compare and discuss the interfaces between responses from students and teachers, as well as the proposed suggestions.

3.1 Transversal Competences

Figure 1 shows a comparison of the total percentage responses from students and teachers regarding transversal competencies in columns. The data points represent the standard deviation used, based on the 2866 responses.

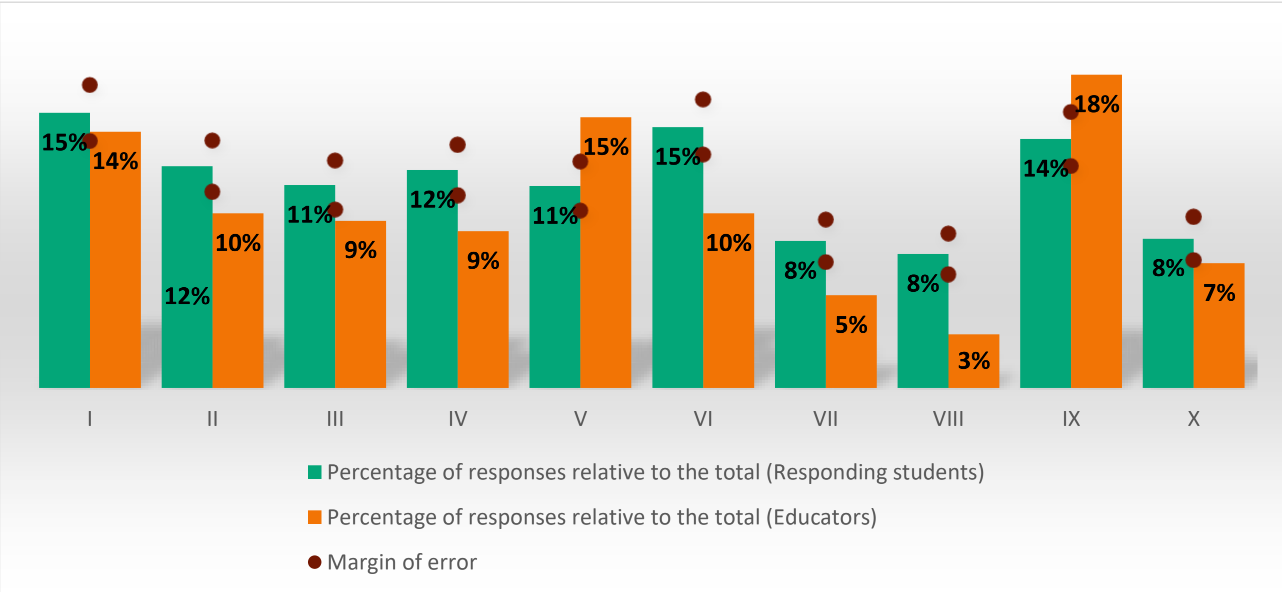

Figure 2 - Comparison between student and teacher responses related to transversal competencies (n=2866)

It is important to highlight that the previously calculated variation of two percentage points on the data may indicate very close responses, with variation tending towards zero, especially when analyzing the extremes.

Considering the data from Figure 1, for competencies I and X, the student-teacher perception was strongly similar. Competency I was one of the most recurring in both groups, indicating that the project developed the skill of evaluation and critical thinking for both students and educators. On the other hand, competency X, although having values close in both groups, was one of the least recurring, suggesting a weakness in the development of decision-making skills. In competencies II and III, the perception was also close, varying by two percentage points, indicating that both groups considered improvements in the ability to select information and face challenges by proposing solutions.

In competency IV, the variation was three percentage points, and it was the highest rated by the students, indicating that they felt stimulated to take initiatives. However, educators pointed out that this competency was only modestly developed. Competency VII also had a variation of three percentage points, following the same pattern of student-teacher evaluation. However, being one of the least frequent, it only reached 5% of the responses, suggesting the need to stimulate interpersonal communication.

In competencies V and VI, the perception between students and teachers was reversed: where students observed the development of planning and organization skills, educators claimed to stimulate innovative creation. Both competencies complement each other and are necessary, reaching higher rates than 10%.

Competency VIII was the least developed according to the evaluators and had the highest disparity in percentage points - 5%, indicating a lack of didactic proposals to deal with unusual situations.

Competency IX was the highest rated among educators and the third highest rated among students, showing the development of problem-solving skills in face of challenges.

Finally, a weakness is delineated in competencies IV and V, in which the behavior stood out: teachers expected the development of certain skills that were not effectively realized by students. This becomes a concern as the objective of the PAEs is to develop all competencies equally.

3.2 Technical Competences

Figure 2 presents, in columns, the comparison of total responses from students and teachers in percentage terms regarding the technical competencies of the PAEs. The data points represent the standard deviation used, based on 2866 voted competencies. Again, it is worth mentioning that the previously discussed variation of two percentage points on the data may indicate very close responses, with variation tending towards zero, especially when analysing the extremes.

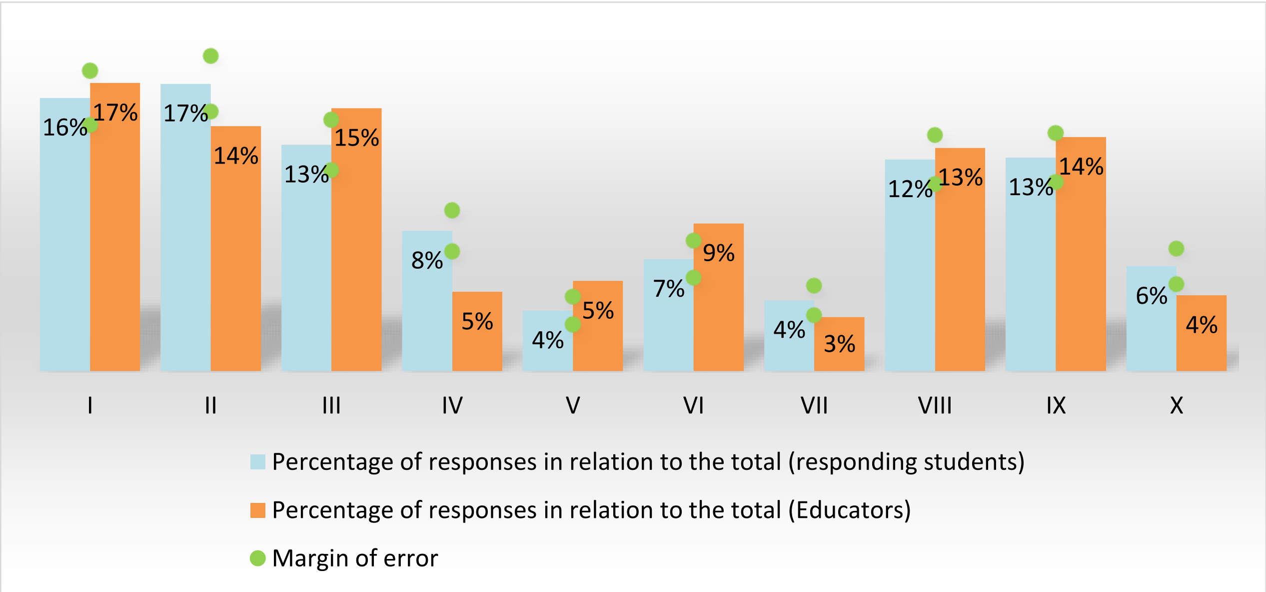

Figure 3 - Comparison between student and teacher responses related to technical competencies (n=2866).

Based on the data, in competencies I, V, VII, VIII, and IX, the perception of students and teachers was similar, with a difference of only 1 percentage point.

Competencies VIII and IX were more frequent, highlighting the development of abilities to formulate and conceive innovative and desirable solutions, autonomous learning, and focus on understanding the potential of new technologies and the opportunities they can open. On the other hand, competencies V and VII were the least frequent for both groups, indicating a lack of learning in communication and knowledge of ethical norms and laws.

In competencies III, VI, and X, the variation was 2 percentage points, which also indicates close perception, highlighting the learning of abilities in conception, projection, and creative analysis. In competencies VI and X, it can be inferred that there was a lack of proposals for working in multidisciplinary teams and limited exploration of knowledge from the productive sector.

In Figure 2, competencies II and IV had the highest difference in percentage points. However, competency II was the most developed, according to the students, and the second most developed among teachers, while competency IV was timidly explored in the projects, suggesting that more focus is needed on implementation, supervision, and control of solutions.

4 Conclusion

In response to the National Curricular Guidelines for Engineering Courses, the evaluation conducted in the IMT for the Integrated Learning Projects (PAEs), based on the categories proposed by Palú, Mattasoglio Neto, and Matta (2022), has proven to be a promising tool, considering the data collected that align the expectations of the instructors with the perception of the students upon completion of the course. A positive response is evident in terms of the efficiency of implementing the competencies for project evaluation: often, the expectations of the instructors are reflected in the perception of the students, confirming the alignment of teaching goals with the technical and interpersonal development of the students. Overall, it was found that the perceptions of students and instructors aligned in the majority of responses, indicating the effectiveness of the evaluation instrument.

Furthermore, proposals for improvement can be considered based on the analysis conducted, contributing to greater effectiveness in learning and teaching. Challenges remain in certain competencies. Notably, Category VII of the technical competence, which refers to "knowing and applying legislation and regulatory acts ethically in the exercise of the profession," and Category VIII of the transversal competence, which refers to "ability to deal with the unexpected/work in uncertain environments (resilience)," could be areas for re-planning and inclusion in the PAEs.

Considering the experience described in this article, it is evaluated that the positive results presented by the methodology have allowed for a deeper understanding of the competencies, weaknesses, and strengths developed by each project. Now, the projection is to mirror this approach in the mandatory curriculum disciplines: it is expected to implement this systematic and comprehensive framing of competencies in order to gradually refine and deepen the quality of teaching and the support offered to students, as well as provide more concrete and instructive feedback to the school's faculty.

5 References

BOTELHO, Vitória Bento; MATTASOGLIO Neto, Octávio; LIMA, João de Sá Brasil. Comparação entre as competências do Grand Challenges Scholars Program e das DCNs do curso de graduação de engenharia. In CONGRESSO BRASILEIRO DE EDUCAÇÃO EM

ENGENHARIA, 2020, Bento Gonçalves, RS. Anais. Disponível em: http://www.abenge.org.br/sis_artigo_doi.php?e=COBENGE&a=20&c=3016. Acesso em: 04 abr. 2023.

BRASIL. Ministério da Educação e Cultura. Conselho Nacional de Educação. Câmara de Educação Superior. Parecer CNE/CES nº 438/2020, de 10 de julho e 2020. Diretrizes Curriculares para o curso de administração. Diário Oficial da União, 13 de outubro de 2021. Brasília, DF, edição193, seção 1, Página 222. Disponivel em: https://normativasconselhos.mec.gov.br/normativa/view/CNE_PAR_CNECESN4382020.pdf?query=Curr%C3%ADculos. Acesso em: 04 abr. 2023.

BRASIL. Ministério da Educação e Cultura. Conselho Nacional de Educação. Câmara de Educação Superior. Resolução CNE/CES nº 5, de 8 de março de 2004. Diretrizes Curriculares para o curso de design. Diário Oficial da União, 15 de março de 2004. Brasília, DF, seção 1, página 24. Disponível em: https://normativasconselhos.mec.gov.br/normativa/view/CNE_rces0504.pdf?query=Normas%20estaduais. Acesso em: 04 abr. 23.

BRASIL. Ministério da Educação e Cultura. Conselho Nacional de Educação. Câmara de Educação Superior. Resolução CNE/CES nº 2, de 24 de abril de 2019. Diretrizes Curriculares para os cursos de engenharia. Diário Oficial da União, 26 de abril de 2019. Brasília, DF, nº 80, seção 1, página 43. Disponível em: https://normativasconselhos.mec.gov.br/normativa/view/CNE_RES_CNECESN22019.pdf. Acesso em: 04 abr. 2023.

BRASIL. Casa Civil. Lei Nº 9.394, de 20 de dezembro de 1996. Diretrizes e bases da Educação Nacional. Diário Oficial da União, de 23 de dezembro de 1996. Brasília, DF, página 27833. Disponível em: http://www.planalto.gov.br/ccivil_03/leis/l9394.htm. Acesso em: 04 abr. 2023.

CHINALLI, Didiane Vally Figueiredo; Nexialistas: Os designers do conhecimento e a nova era da tecnologia da educação. UNAERP – Universidade de Ribeirão Preto. 2013. Disponível em: https://www.unaerp.br/documentos/1468-166-462-1-sm/file. Acesso em: 04 fev. 2022.

DEVORE, Jay L. Probabilidade e Estatística para Engenharia e Ciências. [S.l.]: Cengage Learning. 2006.

MATTA, Eduardo Nadaleto et al. The construction of the project evaluation concept in a team of teachers. In: PROCEEDINGS: FIFTH INTERNATIONAL SYMPOSIUM ON PROJECT APPROACHES IN ENGINEERING EDUCATION, PAEE-LE, 2018. UNB, Brasília, 2018. Disponível em: http://repositorium.uminho.pt/bitstream/1822/66546/1/2018%20_conference%20PAEE_ALE_Aval_Mau%C3%A1_%20Matta_Octavio_Lima_Mesquita.pdf. Acesso em: 04 abr. 2023.

MATTASOGLIO Neto, Octavio; LIMA, Rui M; MESQUITA, Diana. Changing an Engineering Curriculum through a Co-Construction Process: A Case Study. International Journal of Engineering Education, v. 35, n. 4, pp 1129-1140, october 2019. Disponível em: https://www.researchgate.net/publication/336493123_Changing_an_Engineering_Curriculum_through_a_Co-Construction_Process_A_Case_Study. Acesso em: 04 jun. 2023.

MESQUITA, Diana; LIMA, Rui M; FLORES, Maria Assunção. Developing professional competencies through projects in interaction with companies: A study in Industrial Engineering and Management Master Degree. In: PROCEEDINGS: FIFTH INTERNATIONAL SYMPOSIUM ON PROJECT APPROACHES IN ENGINEERING EDUCATION, PAEE'2013. Eindhoven, The Netherlands. 2013. Actas: PAEE'2013. Disponível em: https://www.researchgate.net/publication/270823446_Developing_professional_competencies_through_projects_in_interaction_with_companies_A_study_in_Industrial_Engineering_and_Management_Master_Degree. Acesso em: 04 abr. 2023.

PALÚ, Matheus Ferreira; MATTASOGLIO Neto, Octavio; MATTA, Eduardo Nadaleto. Multidisciplinary projects for Engineering, Business Administration and Design programs: Construction and mapping of common skills through an analysis instrument. PAEE ALE, 2022. Universidade de Alicante, Espanha. 2022. Disponível em: https://zenodo.org/record/7057636. Acesso em: 04 abr. 2023.

Sustentável dessa Inovação. Lecture offered at "Engineering Education for the Future". Instituto Tecnológico de Aeronáutica. 2019. ITA, Brasil, 1st edition. Disponível: http://web.if.usp.br/bib/pt-br/notícia/ita-realiza-o-1º-"engineering-education-future". Acesso em: 04 abr. 2023.

SOUZA, Junior, José Carlos de. Instituto Mauá de Tecnologia. Mauá sob a óptica do Nexialismo! Youtube. 2019b. Disponível em: https://www.youtube.com/watch?v=yRUndB0g1gs. Acesso em: 04 fev. 2022.

SOUZA, Tatiene Correia de. Intervalo de Confiança - Margem de Erro . Universidade Federal da Paraíba (UFPB). 2014. Disponível em: http://www.de.ufpb.br/~tatiene/Disciplinas/2014.2/Slides/MargemErro.pdf. Acesso em: 02 abr. 23.

SESOKO, Veronica Mariti; MATTASOGLIO Neto, Octavio. Análise de experiências de problem e project based learning em cursos de engenharia civil. In: XLII CONGRESSO BRASILEIRO DE EDUCAÇÃO EM ENGENHARIA. Juiz de Fora, MG. 2014. Disponível em: https://www.researchgate.net/publication/310322107_ANALISE_DE_EXPERIENCIAS_DE_PROBLEM_E_PROJECT_BASED_LEARNING_EM_CURSOS_DE_ENGENHARIA_CIVIL. Acesso em: 02 abr. 2023.

Introducing STEM projects in multidisciplinary teacher training

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Abstract

In recent years, the world's population has been forced to make several changes and adaptations, sometimes challenging ones. In this scenario, technology stood out and brought solutions to various setbacks, changing views and customs forever. Professionals from all areas have become hostages of technology, needing to explore it. With this new step taken in many areas, the space conquered by technology has become fixed, making it part of everyone's daily life. From this point onwards, there was a growing incentive for the inclusion of students in STEM areas, given society's growing demand for professionals with knowledge in these areas. In the literature, there are several studies on STEM areas, but it is rare to find schools that integrate STEM knowledge in developing countries. This is mainly because education professionals are not qualified enough for the application of such methods. A possible solution to this problem is clear, complementing the training of subject-specific teachers in interdisciplinary STEM content. Therefore, in this article the focus is to detail a training carried out with teachers to qualify them in the STEM areas. In this training, volunteer teachers from public high and elementary schools who teach different subjects were submitted to classes, using active methodologies, addressing three subjects associated with the STEM areas: modeling and 3D printing; computational thinking, algorithms and programming; electronics and microcontrollers. The classes and materials were developed by a group of engineering students under the supervision of Ph.D. professors in engineering. The training was given by approaching several didactic and technical elements, in addition to clarifying several other elements that could be included based on the specific knowledge of each professional. Based on this, this article will highlight the stages of development and application of the training as well as the discussion about the results and improvements to be made.

Keywords: Active learning; Educational Robotics; Hands on activities; Project approach.

1 Introduction

Recently, the world has found itself in need of exploring technology in all areas, and for all people, everyone has become hostage to technology to carry on with life. One of the many sectors affected was education, which until then had its methodologies mostly identical to those used when the classroom was created, hundreds of years ago. According to Lima (2021), this scenario brought the use of educational technologies to carry out school activities to the center of the educational debate.

In this sense, the STEM disciplines (Science, Technology, Engineering, and Mathematics) entered the agenda. "Education needs to be much more flexible, hybrid, digital, active, and well-diversified", observes Lima (2021, p. 3, our translation)1, making evident the need for both the teacher and the student to become familiar with such matters, where the teacher receives the possibility to make changes in the methodologies used in the classroom and students are prepared for the future where, regardless of the area they decide to follow, they will need technology and related knowledge.

Thus, the use of educational robotics has emerged as an effective technique for teaching and learning STEM subjects. Due to its multidisciplinary nature, robotics requires a series of steps, ranging from planning to assembly and programming of the robot. For a robot to function properly, it is necessary to combine knowledge of mechanics, programming, and electronics. When used as a teaching method, robotics can help students to understand physical and mathematical concepts and also acquire knowledge in programming and electronics.

Additionally, robots arouse great curiosity in students to persist in looking for a solution when faced with assembly and programming problems. In classes of this type, robots with different purposes that have different electronic components and require assembly and specific codes for their operation can be used. This detail can make the use of robots in the teaching of STEM subjects very difficult, demanding greater care from the teacher when designing the class. On the other hand, this complexity can be used to awaken students' creativity to solve problems involving the robot, as long as the teacher has control of this complexity.

For learning to be even more effective, active learning methods and strategies can be used in classes. Active learning aims to make the class more dynamic and interactive, using games, debates, and other forms of interaction. As Felder & Brent (2009, p.2) state: "Active learning is anything course-related that all students in a class session are called upon to do other than simply watching, listening and taking notes". The authors also explain that active learning can occur when students ask questions, for example, or propose solutions to solve problems, work individually or in small groups to solve problems, and share the answers. Felder & Brent (2009, p2) also observe that the teacher is not using an active learning approach when he simply gives lectures, asks questions that only a small number of students answer, or conducts debates in which only a few students actively participate. Therefore, the teacher must be careful when preparing and scheduling the class so as not to lose the characteristics of a class based on active learning.

However, adopting a teaching-learning method that is very different from what teachers and students are used to can be a big challenge. The importance of the teacher's role in the implementation of active methodologies is evident. Several studies highlight the teacher's role as a key element in knowledge management, thus, teacher training should cover several dimensions of learning: interaction, cooperation, cognition, metacognition, and affection (Medeiros & Faria, 2023).

Teacher training is often carried out in traditional courses that do not work in an interdisciplinary way. One way to complement the training of teachers already working in secondary schools is to supplement their knowledge with the necessary technological areas. Our approach to these trends is based on three training workshops for secondary teachers, based on concepts used in the so-called maker movement.

This article discusses the methods of developing the workshops, their content, and the results that were obtained through feedback from the teachers who participated. In 2020, an article was published at this same congress that showed workshops with a similar format, but the target audience was undergraduate students who would eventually replicate these workshops with high school students as their target audience. This time, the target group is different: high school teachers who intend to incorporate the knowledge gained in the workshops into the classes they teach.

The paper is divided into a few sections. In the first section, the relevance of the theme for society is discussed. In the second section, the type of methodology used in this research is explained, while in the third section, there is a literature review on the subject, divided into sub-topics on Active Learning. In the fourth section, the research results are discussed, where the three workshops are explained and the questionnaires sent to all students present at the workshops are analyzed. In the penultimate section, the conclusions and implications of the workshops for the students in question are presented. Finally, in the last section, the bibliography on the theme developed is provided.

2 Research Methodology

The current work analyzes the results obtained from workshops developed and carried out by engineering students with a focus on STEM areas. Workshops were developed and implemented on different days. It was decided to hold the workshops both remotely and online, being able to reach any interested person regardless of physical distance. The target audience of such workshops is high school and elementary school teachers, regardless of their knowledge and the classes they teach in schools. The purpose of the workshops was to bring knowledge of the STEM areas to such teachers so that they could spread this knowledge to their students easily and practically. For this to be possible, it was necessary to study, research, and develop the content to be taught in the workshops to teach teachers important topics and at the same time show how they can relate these topics to their classes in schools.

The content developed in the workshops was jointly defined by two engineering students and three engineering professors, based on previously applied workshops, in which the focus was different, but the content is consistent with the current objective (Costa et al., 2020a)

The first workshop was entitled 3D Modeling and 3D Printing and aimed to introduce CAD software, explain the theory behind modeling, and generate a new part in the presented software. The idea circled stimulating the teachers' creativity so that they could in the future create useful models for their classes, in addition to being able to pass the knowledge on to their students. The workshop also brought 3D printing, where teachers could follow the configuration and calibration of a 3D printer that uses the FDM (Fused Deposition Modeling) technique, ending the workshop with the printing of a part modeled in class.

Then, the second workshop, named Notions of Programming, Electronics, and Arduino, was designed to bring an introduction to computational thinking, showing participants the form of reasoning used in computationally solving problems. With such reasoning understood, one can go one step further and start programming a board named Arduino, understanding its operation and the possibilities it brings. Finally, the basics of electronics were presented and put into practice together with several exercises that also used Arduino.

The next applied workshop brought an integration between the knowledge obtained in the previous workshops, it was designed so that the teachers would be able to perceive the existing possibilities from the content presented in the previous workshops. In particular, a competition between teams was developed, but it was shown the innumerable possibilities that the teacher can approach in the classroom, focusing on his subject and using the new knowledge acquired.

At the end of the workshops, forms created by the team were shared with the participating teachers to obtain feedback on the applied teaching methodologies, making it possible to understand the points to be improved, the points to be removed and the points to be inserted.

3 Literature Review

Prince & Felder (2006) state that traditional teaching methods, in which the teacher simply transmits information and then assigns homework, are inefficient and demotivating. This approach causes students to focus only on activities and tests, without understanding why they should learn the content or how to apply it in practice. This can be particularly problematic for students who need to learn how to use their theoretical knowledge to solve real problems.

Berbel (2011) points out that active learning methods and strategies seek to create new ways of learning to solve real or simulated problems resulting from social practices. The objective is to learn through practice, encouraging students' autonomy and making them assume a prominent role in the learning process, through debates, group activities, and examples that bring the topic closer to the student's reality.

In their recommendations to stimulate the active participation of students in the classroom, Faust & Paulson (1998) state that active learning is beneficial for the development of critical, writing, and analysis skills, in addition to improving argumentation skills. These authors emphasize the adaptability of active learning methods and strategies, which can be adjusted to meet the needs of each student and their specific learning style.

According to Srinath (2014), it is crucial to use practical examples to help understand the concepts presented and allow students to visualize the applications. Examples should be used to illustrate concepts and make them more accessible, as well as teach how to apply knowledge in other situations. Demonstrations are fundamental to establishing connections between theory and practice, without eliminating theory, but complementing it.

Tharayil et al. (2018) state that, although students usually demonstrate a positive reaction toward active methods, some of them may resist this approach. This resistance can be minimized through simple actions such as walking around the classroom and talking to students individually or in groups. The teacher should create a welcoming and comfortable environment for students so that they feel free to ask and answer questions without feeling intimidated.

Felder & Brent (2009) propose several strategies for students' active learning, including the thinking-aloud pair problem-solving technique (TAPPS). In this technique, a student assumes the role of explainer and describes concepts or texts step by step to other students, while they question the explainer whenever there is doubt or some aspect that needs clarification.

The role of the student as a tutor is fundamental in the active learning strategies, as the student must study and prepare for the class, in addition to analyzing how to transmit knowledge to other colleagues. In this way, the student becomes the protagonist of his learning, as he needs to make an effort to understand well the content to be explained and answer possible questions from colleagues. Thus, when acting as a tutor, the student learns both in the preparation and in the execution of the class, and when he manages to explain a concept to others, he proves his understanding of the content (Srinath, 2014).

STEM can be considered an active learning methodology and is characterized by stimulating constructive processes of action-reflection-action according to Freire (2006) and which emerged from hybrid teaching, or blended learning, which is characterized by part of learning in an online formal educational program (Horn, Staker, 2015).

McDonald (2016) cites the need to invest in the professional development of STEM teachers for the adoption of new strategies and methodologies. Tharayil et al. (2018) point out that it should be considered that each teacher has different styles and educational contexts for the adoption of new pedagogical strategies, that is, there is a need to present different possibilities for the integration of teachers into active methodologies and STEM.

4 Results

In this section, we discuss the details of the workshops held and also present an analysis of the questionnaires answered by the teachers who participated in the workshops. In this edition, we had two classes, one in-person and the other remote. All activities were the same for both classes, but some adaptations were made in the remote class lectures due to logistical issues and such.

4.1 3D Modelling and Printing Workshop

The first workshop held was on 3D modelling and printing. This workshop aimed to teach teachers to model simple parts that they could print on an FDM 3D printer. For modelling, the TinkerCad website was used due to the fact that it is free and can be opened in a browser, without the need for a powerful computer. In the second subject of the workshop was presented a 3D printer model Criality Ender 3 (model chosen by the great cost-benefit and for being accessible) and shown how to make a print, since the slicing (using the software Ultimaker Cura), choice of raw material (in the workshop was used the material PLA, but presented other types), calibration of the machine, until get the print ready. At the end of the workshop, an introduction to computational thinking was presented in preparation for the second workshop. Following the methodology of the previous workshops documented in (Costa et al. ,2020b), the workshop was divided in some stages:

1. The history of modelling was addressed by going through its emergence in its primitive and completely different form from today, arriving at the current modelling, highlighting the changes in the methods used and the objectives to be achieved with it;

2. A new software, TinkerCad, was introduced for online modelling, eliminating the need for downloading software and specific hardware to support the program. Exercises were conducted in a guided manner within the program;

3. 3D printing was introduced, the history of the 3D printer was shown, and its operation was explained;

4. Applications and areas in which 3D printing and 3D modelling are used were presented;

5. The most common types of 3D printing and the types of movements used in the printing process were demonstrated;

6. The part preparation software for printing, Utimaker Cura, was introduced. The main aspects to be taken into consideration when setting up a print were explained;

7. An Ender 3 FDM printer was used, calibration was performed, material was loaded using PLA plastic, and finally a part was printed from start to finish;

8. An introduction to computational thinking was presented, followed by gamified exercises that started in the classroom and were continued at home.

4.2 Arduino Programming Workshop

The second workshop aimed to introduce a didactic microcontroller called Arduino and showcase its numerous possibilities for academic use. To utilise the Arduino, it is necessary to write code, and therefore, introductory programming content was included. To facilitate understanding, computational thinking was introduced at the end of the previous workshop, with gamified exercises given to be completed at home, allowing participants to start their introduction to programming with some prior knowledge. In addition to programming, basic electronics knowledge is required to work with the Arduino as it is an electronic component that can be associated with various others. For this reason, the workshop also included an introduction to basic electronics with practical exercises. Similarly to the previous workshop, this one was divided into parts:

1. It began clearing up some remaining doubts about computational thinking covered in the previous workshop;

2. The Arduino microcontroller was introduced, and everyone received a sample to have hands-on experience. The model used was the UNO, which was chosen for being one of the most didactic and less expensive options, besides presenting enough pins for the proposed activities.

3. It was explained the need to use a platform to program the Arduino, showing the possibility of creating and testing codes virtually through the software previously used for modelling TinkerCad;

4. The Arduíno IDE software was introduced, which is used to program the physical Arduíno. Participants were taught how to use the IDE, its functionalities, and the main functions required to proceed with the workshop;

5. Some simple exercises were carried out to test the functioning of the IDE;

6. The basics of electronics were explained, presenting the most fundamental concepts and showing practical examples;

7. Some basic electronic components for Arduino usage were introduced along with explanations about their functionalities and utilities;

8. Exercises were started using the components presented in conjunction with Arduino, programming the functioning of such components. Circuit designs were shown to assist in assembly;

9. Some other components, which would be useful for the third workshop, were gradually introduced, and exercises were carried out each time a new component was presented to understand its operation and manipulation in practice.

Figure 1. Example of a circuit shown to assist in the assembly of physical circuits on the left and the circuit used in the third workshop that follows the same pattern.

4.3 Knowledge Integration: Robot Car Construction

This workshop aims to bring together the knowledge acquired in the two previous workshops and assemble the robot designed by the tutors. The robot has its entire structure modelled by the workshop tutors and 3D printed using an FDM printer similar to the one shown in the first workshop, using all the content taught in the first class. The robot contains an Arduino Uno microcontroller, the same as used by the students in the second workshop, so to assemble the robot's circuits, electronic components, and motors, and to program it, all the content from the second class is sufficient. The robot is powered by two geared DC motors controlled by an H-bridge module and powered by a combination of 1.5V batteries. The robots are controlled by Bluetooth through an Android app developed on the AppInventor platform. Due to the short class period, it was not possible for participants to develop the app, so they used a standard app developed by one of the tutors.

Figure 2. Photo of robots assembled by participants from both teams alongside views of the software used to model the 3D-printed robot parts.

The final idea of the workshop is to have participants split into two teams and each team builds three robots. In the end, a soccer competition is held with the robots assembled by the teams, and the strategies of the teams are determined by the algorithm they implemented in their robots' programming. With this in mind, the workshop was divided as follows:

1. Physical assembly of the robot from printed parts;
2. Assembly of the electronic circuit, sensors and motors;
3. Robot programming, including the game strategy devised by each team;
4. Competition.

Figure 3. Photograph of the teams assembling the robots in the in-person class. On the left, the green team, and on the right, the purple team.

All activities were carried out following the active learning methodology, and at no time did the guiding tutors provide explanations on what should be done, being available only in case of the need for intervention to solve problems.

4.4 Questionnaires analysis

After the workshops, participants from both groups filled out a questionnaire with their impressions and reflections on the practice. They were invited to reflect on the strategies and methods used during the workshops, including flipped classroom, guided practice, and hands-on activities.

Based on the questionnaire responses, it was observed that the participants' attendance was high and satisfactory, even in the remote class group. As for the participants, some are undergraduate students at the University of Brasília, but the majority are teachers from the public school system. All those who attended most of the classes reported feeling highly motivated by the robot and the method used in the workshops.

All the people who attended the in-person classes were engaged and managed to build the robot, but that was not the case for the remote class participants. Even though they received the list of materials in advance, some were unable to organise themselves to acquire the components and print the parts that make up the robot. Some did not have access to a 3D printer at the school where they work, and others lived in rural areas that do not have access to electronics equipment stores, for example. However, everyone participated in the activities using simulators proposed by the tutors in order to mitigate this problem.

The vast majority of participants reported having fully understood the concepts and contents covered in the course, and that they can easily apply these concepts in the classes they teach, which is the main objective of these workshops. The following graphs illustrate better the answers to the questionnaires from who participated remotely.

Figure 4. Graphs of the responses from remote participants.

Some of the answers when asked about what they thought more useful on the workshops:

“I believe that the most profitable thing in any training is meeting people and exchanging experiences/ideas, even remotely. Regarding the course itself, there were many things: learning about the 3D printer (something new in schools), getting to know TinkerCad and its applicability (I thought it was fantastic and very applicable to the classroom), being introduced to programs that improve thinking computational (can be used a lot in classes), understand how the programming-Arduino interaction works, test possibilities in assembling the cart and think of new possibilities.”

“I liked all aspects, especially in the area of computational knowledge. And in the assembly of the cart. The way the course was distributed, I managed to have a broad knowledge from how it works to the final assembly and in operation.”

“I found all the classes well explained, which made it easier to understand.”

5 Conclusion

According to the observed results, the workshops achieved the proposed objectives, providing teachers with opportunities to reflect on the most diverse themes while carrying out the project of a robot cart. The active methodologies proved to be effective in this process and it was possible to highlight several possibilities for their application in the different areas taught by the participating professors.

The materials chosen for the application of the workshops are excellent choices, arousing the interest, curiosity, and motivation of the participants, making it clear how, with its playful and practical nature, this material can be easily used in the classroom as a way of teaching and capturing students' attention and desire to learn. Disciplines that often become the target of rejection can begin to be addressed in other ways that are more attractive and fun for students.

Needs for pauses and repetitions were observed for the complete understanding of the participants, given the fact that some had had their first contact with programming and electronics. Time proved to be a little short to assemble the robot car and the robot soccer competition as planned, but each team managed to finalize and program at least one copy of the car and it was possible to test them in a brief game in the mounted field.

The results and their comparison with the planning show that it is necessary to adjust activities over time. It is necessary to base it on the experience obtained with time spent by people who have never had contact with the car and its assembly and even with programming and electronics, all these details being influential in the final time used.

With such results, the workshops will be improved for new applications and new workshops can be developed. It is hoped, therefore, that this work has contributed to the reflection of the theme in general and brings encouragement to teachers and schools that have not yet had contact with such methodologies and subjects.

6 References

Allen, D. E., Donham, R. S. & Bernhardt, S. A (2011). Problem-Based Learning. New Directions For Teaching And Learning. 21-29. doi: 10.1002/tl.465

Barbalho, S. C. M., Reis, A. C. B., Bitencourt, J. A., Leão, M. C. L. A. & da Silva, G. L. (2017). Project Based Learning approach for Production Planning and Control: analysis of 45 projects developed by students. Production, São Paulo, 27, 1-16. doi: 10.1590/0103-6513.225916.

Berbel, N. A. N. (2011). Active methodologies and the promotion of student autonomy. Semina: Social Sciences and Humanities, 32 (1), 25-40. doi: 10.5433/1679-0359.2011v32n1p25.

BNCC, Ministry of Education (2015). National Common Curriculum Base. Brasília, MEC. Available in: <http://basenacionalcomum.mec.gov.br/images/BNCC_EI_EF_110518_versaofinal_site.pdf.>.

Brazilian Association of Higher Education Maintainers. National Curriculum Guidelines of the Engineering Undergraduate Course. Available in: https://abmes.org.br/arquivos/legislacoes/Resolucao-CNE-CES-002-2019-04-24.pdf.

Cambruzzi, E. & De Souza, R. M. (2015).Educational Robotics in the learning of Programming Logic: Application and Analysis. IV BRAZILIAN CONGRESS OF INFORMATICS IN EDUCATION, 2015, Maceió. Brazilian Computer Society - SBC. doi: 10.5753/cbie.wie.2015.21.

Costa, R. A., Batista, F. A., Santos, L. C. P., Oliveira, M. J. A., Viana, D. M., Silva, J. Y. M. A., Cornelio, E. M. B, Silva, F. R., & Koike, C. M. C. C. (2020a). Capacitação de tutores para estratégias de aprendizagem ativa em áreas de STEM. In: XLVIII Congresso Brasileiro de Educação em Engenharia (COBENGE) e III Simpósio Internacional de Educação em Engenharia da ABENGE.

Costa, R. A., Batista, F. A., Santos, L. C. P., Oliveira, M. J. A., Viana, D. M., Silva, J. Y. M. A., Cornelio, E. M. B, Silva, F. R., & Koike, C. M. C. C. (2020b). Tutoria e múltiplas abordagens em oficina de modelagem e impressão 3D. In: XLVIII Congresso Brasileiro de Educação em Engenharia (COBENGE) e III Simpósio Internacional de Educação em Engenharia da ABENGE.

Faust, J. L. & Paulson, D. R. (1998). Active learning in the college classroom. Journal on Excellence in College Teaching, 9 (2), 3-24.

Felder, R. M. & Brent, R. (2009). Active Learning: An Introduction. ASQ Higher Education Brief, 2, 1-5.

Horn, Michael B., Heather Staker, and Clayton Christensen. Blended: usando a inovação disruptiva para aprimorar a educação. Penso Editora, 2015.

Hmelo-Silver, C. E. (2004). Problem-Based Learning: What and How Do Students Learn?. Educational Psychology Review, 16(3), 235-266.

Lima, J. R. R. (2021). A implementação do ensino híbrido no período pós-pandemia. Revista Ibero-Americana de Humanidades, Ciências e Educação, 7(2), 10-10.

Marcussi, L. D., Guedes, C., Filho, R. G. D. M., Filho, R. M. S. & Junior, C. R. B. (2016). Pesquisa no Ensino de Algoritmos e Programação nas Engenharias: Estudos e Resultados Preliminares. Simposium of Production Engineering.

Medeiros, M. F & Faria, E. T. (2003). Educação a distância: cartografias pulsantes em movimento. EDIPUCRS, Porto Alegre.

Mcdonald, Christine. STEM Education: A review of the contribution of the disciplines of science, technology, engineering and mathematics. Science Education International, v. 27, n. 4, p. 530-569, 2016.

Prince, M. J. & Felder, R. M (2006). Inductive Teaching and Learning Methods: Definitions, Comparisons, and Research Bases. Journal of Engineering Education. 123-138.

Srinath, A. (2014). Active Learning Strategies: An illustrative approach to bring out better learning outcomes from Science, Technology, Engineering and Mathematics (STEM) students. International Journal of Emerging Technologies in Learning, 9 (9), 21-25. doi: 10.3991/ijet.v9i9.3979.

Tharayil, S., Borrego, M., Prince, M., Nguyen, K. A., Shekhar, P., Finelli, C. J. & Waters, C. (2018). Strategies to mitigate student resistance to active learning. IJ STEM, 5 (7), 1-16, doi: 10.1186/s40594-018-0102-y.

Volpato, N. (2018). Manufatura aditiva: tecnologias e aplicações da impressão 3D. Publisher Edgard Blucher, 1 ed, 401.

Wildner, M. C. S. (2015). Robótica Educativa: Um Recurso Para o Estudo de Geometria Plana no 9º Ano do Ensino Fundamental. Univates University Center, Rio Grande do Sul.

Wiltgen, F. (2019). Protótipos e Prototipagem Rápida Aditiva - Sua Importância no Auxílio do Desenvolvimento Científico e Tecnológico. doi: 10.26678/ABCM.COBEF 2019.COF2019-0441.

The support of EdTechs in developing new market required engineering professional's skills

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Abstract

The scenario of higher education has changed rapidly and radically in recent years due to the use of new technologies. In this way, the processes of organizing the curriculum, methodologies, times and spaces need to be reviewed. In addition, new social and economic imperatives have made engineering education increasingly important. Engineers play a decisive role in the development of technologies and innovation. Given this, it is necessary that universities take on the role of enabling good professionals that are capable of entering and thriving in the workplace. Thus, it is essential to promote the comprehensive training of these professionals by developing meaningful learning strategies. In this way, EdTechs emerged as companies that promote the fusion between education and technology. It adopts technology as a learning facilitator process and promote the improvement of educational systems. In this way, this article intends to analyze which complementary skills the market has demanded from engineering professionals and how EdTechs can enable students and professionals in this new market. In order to achieve the proposed objectives, the following methodology was designed: identify the required skills in this new market and how and in what proportion EdTechs have enabled this development, through a systematic literature review. According to the literature, 19 skills were listed as necessary for the complete development of the new engineering professional. It was also noticed that there is currently a big availability of content that allows these required skills to be fulfilled. It was then verified that practically in all competences, at least 50% of the existing EdTechs in the Brazilian southeast region, focused on open courses, fill the necessary gaps for this qualification.

Keywords: EdTechs, Competencies, Engineering Professionals.

1 Introduction

Education is part of human essence (SAVIANI, 2007): humans act on nature to ensure their survival and share their knowledge with their peers, creating a process of teaching and learning. Piaget (1970) expands the meaning of education by citing as its objective to form subjects who create different things, not just limit themselves to what their ancestors did (VIEIRA & BARROS, 2021). BECKER F., 2012, refers us to three distinct forms regarding the relationship between teaching and learning in the educational environment: directive, non-directive, and relational pedagogy, based on their epistemological foundations. According to the author, in directive pedagogy, the classroom has a traditional configuration, with the teacher at the center, monopolizing the process with the imposition of their speech. In this context, the teacher believes in the pure transmission of knowledge.

In contrast to the first model, non-directive pedagogy is one in which the teacher assumes the role of someone who assists and seeks to promote the process, facilitating the student's understanding. The hereditary baggage is recognized and respected, and it is "awakened" by the teacher. According to this assumption, the student has the ability to interfere in the physical and social environment that surrounds him/her.

Regarding the third model, relational pedagogy proposes the construction of knowledge based on reflection. This model opens up space for interactivity, participation, and teamwork, which are essential in today's society (RUTZ K. P. et al., 2021).

Recently, universities have recognized the need for curricular reforms to meet the demands of society, identifying that innovations are necessary in higher education today (LIMA & WIEBUSCH, 2018). These authors also state that in order to innovate, it is necessary to understand what innovation is and what its impacts are on the teaching and learning process, to avoid misunderstandings in discussions, planning, and actions. This is because innovation is not just the insertion of technology, it goes beyond technological resources and the institution's infrastructure. Pensin and Nikolai (2013) emphasize that it is necessary to "assume innovation as a guiding assumption of educational practice". Therefore, the university classroom needs to be dynamic and attractive to students, so that they engage with learning (LIMA & WIEBUSCH, 2018). Thus, the scenario of higher education has rapidly and radically changed in recent years due to the implementation of new information technologies. According to MORÁN, 2015, the processes of organizing the curriculum, methodologies, times, and spaces need to be reviewed. The perception is that it is no longer possible to deal with what the future imposes while still relying on practices from the past.

Furthermore, new social and economic imperatives have made education for engineers increasingly important. Engineers play a decisive role in the development of technologies and innovation. Therefore, it is necessary for universities to assume the role of training good professionals capable of entering and thriving in the workplace (TÄKS M.et al., 2014).

Engineers who possess only technical knowledge cannot stand out in the job market, being only executors of known techniques. Thus, in order to remain relevant and adequate to new requirements, it is necessary for them to open up to a new worldview. Therefore, engineering schools face the challenge of providing students with a wide range of skills and knowledge beyond the merely technical (SOUZA et al., 2019), including various transversal skills.

Thus, it is necessary for engineers to develop so-called transversal skills (TS), which encompass characteristics of communication, interpersonal skills, leadership, and problem-solving. Being some of the skills and talents that a person can use in their work, however, there are several other competencies associated with Soft Skills (ANDRADE, 2016, SILVA et al., 2020).

The concept of Soft Skills or transversal skills (HT) emerged, a new definition for the organizational environment, however, Andrade (2016) suggests that it is the set of behaviours originated from personality traits, stimulated or not according to the context of each individual and the stimuli they receive, also considering professional training. A person's formation is linked to the stimuli of the organizational environment, influencing their personality traits and set of behaviours.

The broad access to knowledge and new work possibilities configured from then on have contributed to a restless context (MATTASOGLIO NETO, SOSTER, 2017). The current job market demands that professionals be flexible and make quick decisions, as described by ASSUNÇÃO & GOULART, 2016 who described that the context of technological development evidences situations of unpredictability and instability, demanding immediate and assertive decisions and actions from professionals with specific and suitable competencies for the new reality (SILVA et al., 2020).

In a hyperconnected world, the traditional and century-old configuration of a classroom has increasingly lost space to new ways of thinking about education combined with technological innovations. This mode of teaching is currently delivered by EdTechs, companies that promote the fusion of education and technology. These companies adopt technology as a facilitator of learning processes and improvement of educational systems. Applications, online courses, and new platforms seem to be just the beginning of a great branching out of teaching (NETO MENDONÇA, VIEIRA, ANTUNES, 2018).

FREITAS, 2017, investigated the influence of EdTechs on traditional teaching models, specifically regarding higher education and its process of innovation in teaching and perceived that innovation is a process that depends on involved management and committed teachers to innovate in teaching. This is of utmost relevance because an innovation will be successful if there is planning from university management, infrastructure, changes in teaching, training for teachers, innovative pedagogical practices, and student participation. And it is at this point where EdTechs have filled this gap in the training of engineering professionals, providing support and innovative knowledge.

Thus, this article aims to analyze what complementary training the market has been requiring of engineering professionals and how EdTechs can benefit students and these professionals facing this new market.

2 Methodology

For the construction of this study, an integrative literature review was conducted between November 2021 and December 2022. Articles that addressed the theme of competencies necessary for engineering professionals, education in the present day, technology, and EdTechs were selected. Electronic journals and articles published in the Google Scholar, Scielo, and official websites databases were used. Regarding the study's design, there were two stages: the search for national and international articles evaluated based on their titles and abstracts, using the inclusion criteria previously established. The articles that met the criteria and showed a connection to the theme were added to the study. The search for articles was conducted in Portuguese and English using the search terms listed in Table 1. In the second stage, the selected texts were read in full, interpreted, and synthesized. All articles used were freely accessible.

Table 1. Cross-referencing of descriptors in databases

Database	**Descriptors**
Scielo	"Technology and education", "EdTechs", "Engineer", "SOFT SKILLS"
Google Acadêmico	"Competências dos profissionais de Engenharia", "EdTechs", "Industria 4.0", "Engenharia e tecnologia"
Outros	"Competências dos profissionais de Engenharia", "EdTechs", "Industria 4.0", "Engenharia e tecnologia", "Technology and education", "Edtechs", "Engineer"

Source: Authors

The inclusion criteria for this study were defined as follows: articles in Portuguese and English language, published on engineering professionals and the current job market, how EdTechs assist in the development of competencies and the growth of these institutions in Brazil. Articles between 2012 and 2022 were selected and used as a basis for the topic at hand. Works from previous years were excluded.

3 Results and Analysis

This study was initially composed of a population of 835 articles, resulting from an initial search. Considering the inclusion and exclusion criteria and the combinations of descriptors, a sample of 29 articles was selected. Publications found in more than one database were considered only once.

3.1 Cross-functional skills required of engineering professionals

Taking into consideration that each industrial revolution has been based on a specific technological development, it is logical to assert that, as SCHWAB Klaus (2017) points out, Industry 4.0 will require professionals with a different profile from those demanded by Industry 3.0 and earlier, highlighting that as digitalization and automation of production take place, there will be a displacement of workers with the technologies used in the production process. The author emphasizes that in the future, the talent of the workforce will outweigh capital, representing a critical factor of production.

In this vein, AIRES R. W. A. et al., 2016, argue that the true competitive advantage lies in the capacity and speed of people's learning within organizations. Erol et al., (2016) point out a set of competencies that are essential for the development of engineering activities within a productive environment in the scope of enabling technologies of Industry 4.0: personal, social, action, and domain competencies.

Hecklau et al. (2016) argue for a set of four important competencies to analyze job requirements: technical, methodological, social, and personal competencies. Subsequently, the corporate education system has played a prominent role in building distinctive values for competitiveness, as can be seen in Table 2.

Table 2. Competencies described by authors

Competencies	Authors
Cognitive Skills: Cognitive flexibility, Logical reasoning, Problem sensitivity, Mathematical reasoning, Visualization	WORLD ECONOMIC FORUM (2016)
Creativity	WORLD ECONOMIC FORUM (2016); SORKO, IRSA (2016); VORONINA, MOROZ (2017)
Reproducing simple knowledge	SORKO, IRSA (2016)
Entrepreneurship	CHEN, ZHANG (2015)
Inovation	CHEN, ZHANG (2015); SORKO, IRSA (2016);
Physical Skills: Physical strength, Manual and precision dexterity	WORLD ECONOMIC FORUM (2016)
Healthy Physical	CHEN, ZHANG (2015)
Content Competencies: Active learning, Oral expression, Reading comprehension, Written expression, Digital literacy	WORLD ECONOMIC FORUM (2016)
Interaction with other knowledge areas	CONFEDERAÇÃO NACIONAL DA INDÚSTRIA (2016)
Learning	CHEN, ZHANG (2015)
Communication	CHEN, ZHANG (2015); VORONINA, MOROZ (2017)
Process Competencies: Active listening, Critical thinking, Self-monitoring and monitoring of others	WORLD ECONOMIC FORUM (2016)
Social Competencies: Team coordination, Emotional intelligence, Negotiation, Persuasion, Service orientation, People management	WORLD ECONOMIC FORUM (2016)
Working in a multidisciplinary team	CONFEDERAÇÃO NACIONAL DA INDÚSTRIA (2016)
Social and Moral Responsibility	CHEN, ZHANG (2015)
Independency	CHEN, ZHANG (2015)
Systemic Competencies: Judgment and decision making, Systemic analysis	WORLD ECONOMIC FORUM (2016)
Competence to solve complex problems: Complex problems solutions	WORLD ECONOMIC FORUM (2016); CHEN, ZHANG (2015)
Resources Management Competencies: Financial resources management, Material resources management, People Management, Time management	WORLD ECONOMIC FORUM (2016)
Development sustainability and sustainability	GARBIE (2017)
Technical Competencies: Equipment repair and maintenance, Equipment control and operation, Programming, Quality control	WORLD ECONOMIC FORUM (2016)

Technical knowledge	CHEN, ZHANG (2015); CNI (2016); DELOITTE (2016); VORONINA, MOROZ (2017)

Source: Authors

Given this, the NATIONAL CONFEDERATION OF INDUSTRY (2016) defines that one of the pillars for the development of Industry 4.0 is the development of human resources for the new forms of production, and alerts to the need for professionals with distinct education from the existing ones. The integration of various forms of knowledge, a characteristic of this mode of production, will require multidisciplinary teams with a high level of technical knowledge and the ability to interact with different areas of knowledge.

Miquilim and Silva (2019) advocated for the need for a more comprehensive education for engineers, including training for innovative entrepreneurship, as due to the technological changes experienced, it is understood that the engineering professional must indicate the innovations that will be essential to society. Cala and Borowski (2018) stated that global economies have undergone enormous transformations, generating adversities for companies that could only be faced with the support of the experience, competence, and skills of employees. Thus, it is evident that companies need professionals who are adapted to technological conjunctures and that the engineering professional, due to their profile of conception of goods and services, in addition to the organization of the productive environment, is closely linked to these issues (BASANTE et al., 2018).

The new work demands require employees who know how to communicate, have the ability to coordinate various tasks, ethical judgment, and ease of working in a team (MARTINS, 2017).

According to Costa (2015), the awareness that mastery of Soft Skills not only helps professionals in their search for a position in the professional world but also propels them in their careers, highlights the need to align technical and personal skills in order to achieve professional development.

Analyzing the literature on the subject, 19 Soft Skills were identified, which are also called transferable skills according to LIMA R. M. et al., 2017, or behavioral skills according to ROBLES Marcel, 2012; AHMED, F. et al., 2013. Table 3 shows the skills and their descriptions.

Table 3. Transversal skills (TS) described in the literature

Skill	**Description**	**Authors**
Attention to detail	To pay attention to small details.	SOUZA A.S., 2019;
Argumentation and Persuasion	Being able to express oneself well, clearly present one's ideas to others, gain support, and persuade them to accept one's decisions or preferences.	SOUZA A.S., 2019; LIMA et al. 2017; SORKO, ISRA, 2016; WORLD ECONOMIC FORUM, 2016;
Learning ability	To have the ability to adopt new knowledge or the ability to be a lifelong learner.	SOUZA A.S., 2019; VORONIMA & MOROZ, 2017; CONFEDERAÇÃO NACIONAL DA INDÚSTRIA, 2016; WORLD ECONOMIC FORUM, 2016;
Communication	Having the ability of oral and written communication, as well as being able to listen.	SOUZA A.S., 2019; LIMA et al., 2017; ROBLES, 2012; CHEN, ZHANG, 2015; VORONIMA, MOROZ, 2017;
Creativity and inovation	Encouraging and presenting new ideas.	SOUZA A.S., 2019; LIMA et al., 2017; CHEN, ZHANG, 2015; SORKO, ISRA, 2016; VORONIMA, MOROZ, 2017; WORLD ECONOMIC FORUM, 2016;
Flexibility	Ability to adapt, ease of change.	SOUZA A.S., 2019; ROBLES, 2012; CONFEDERAÇÃO NACIONAL DA INDÚSTRIA, 2016; WORLD ECONOMIC FORUM, 2016;
Time management	Plan your time consciously, analyzing the time spent on specific activities and meeting deadlines.	SOUZA A.S., 2019; WORLD ECONOMIC FORUM, 2016;
Leadership	Having the ability to bring out the best in others, acting sensibly and influencing people.	SOUZA A.S., 2019; LIMA et al., 2017; WORLD ECONOMIC FORUM, 2016;
Foreign languages	To be able to communicate in other languages.	SOUZA A.S., 2019; LIMA et al., 2017;

Networking	Seeking contact with other people who work in the same field.	SOUZA A.S., 2019;
Organizing	Keep your tasks and work environment in order.	SOUZA A.S., 2019; LIMA et al., 2017;
Objectives orientation	Having the ability to focus on your goals and work towards achieving them.	SOUZA A.S., 2019; LIMA et al., 2017;
Proactivity and initiative	Exceeding expectations and taking initiative. In addition, it is about taking actions in advance of a task or gathering information about a particular subject.	SOUZA A.S., 2019; LIMA et al., 2017; CHEN, ZHANG, 2015;
Problem solving	To be able to solve problems as promptly and effectively as possible, often resorting to creativity.	SOUZA A.S., 2019; CHEN, ZHANG, 2015; WORLD ECONOMIC FORUM, 2016;
Responsibility	Being accountable for one's actions and responsibilities assigned to them.	SOUZA A.S., 2019;
Know how to listen	Accepting others' opinions, not prejudging what is being said, and paying attention to the speaker.	SOUZA A.S., 2019; WORLD ECONOMIC FORUM, 2016;
Pression tolerance	Keep calm and focused in surprising and/or stressful situations.	SOUZA A.S., 2019;
Decision making	To know how to choose an effective action plan for a given situation.	SOUZA A.S., 2019; WORLD ECONOMIC FORUM, 2016;
Teamwork	Being able to work with different types of people, expressing your opinions and knowing how to listen to others.	SOUZA A.S. , 2019; CONFEDERAÇÃO NACIONAL DA INDÚSTRIA, 2016;

Source: Authors

In addition to the previously mentioned skills according to the WORLD BANK, 2018, there are three other types of skills that are increasingly important in the workplace, namely advanced cognitive skills, socio-behavioral skills, and combinations of skills that are predictive of adaptability. Building these skills requires a strong foundation of human capital and lifelong learning (WORLD BANK, 2018; PENHAKI, 2019).

Therefore, it can be seen that the professional situations that an engineer needs to face require a series of behaviors, making it desirable that these skills are developed from university. However, there is a predominance of traditional methods in teaching. CAMPOS, L.B.P. et al., 2018 suggested that pedagogical practices and educational processes should be rethought and revised to enable not only the absorption of technical knowledge, but also the development of the skills that are important for the career (SOUZA A.S. et al, 2019).

The universities are expected to prepare professionals who can work both in technical areas and in those involving people management, knowledge, and process management, as well as possess competencies in leadership, communication, and entrepreneurship (STURM C.H. et al., 2015). This training methodology, which seeks to develop multidisciplinary competencies in engineering students, known as Technological Education, provides a more robust and reliable production system, meeting the needs of the labor market. This was possible because this process involves education, technology, science, technique, and ethics to train critical citizens capable of understanding the world around them, but not only with a focus on technology, with the main target of this training being the human being (CARVALHO, TONINI, 2017; ZANETTI Micheli et al., 2021).

3.2 Impact of EdTech on the development of transversal competences of engineering professionals

TOEBE in 2016 demonstrated that the integration of educational technologies requires actions both in the educational management scope and in teaching practices, and that technological-pedagogical fluency is paramount to pedagogical innovation. In this perspective, they problematized the concepts of pedagogical and technological innovation for teachers, and their results promoted the student as the protagonist of the teaching and learning process and, for the teacher, enabled self-assessment, reflection, and reconstruction of pedagogical practice (VIDAL, MERCADO, 2020).

Among the determinants of academic success, active participation and student engagement stood out. It was noticed that when students took advantage of the diversity of opportunities offered by educational institutions, getting involved in research, teaching, extension, and training, they presented better results in the job market. In engagement, it is also possible to identify students' satisfaction with their education, a sense of belonging, where they feel part of the university, responsible for their formative process, and therefore seek to perform well academically. In this sense, involvement in institutional activities demonstrated the relevance of integration into university life for academic success (MITCHELL G. W. et al., 2010). In the same study, it was also possible to observe that online education, which has been more recently propagated by EdTechs, will become a more economical and efficient way of educating students.

According to the BRAZILIAN STARTUPS ASSOCIATION, 2020, the online content offering platform is the type of technology that has had the most growth recently. Table 4 shows the type of technology and the products offered. This platform displays courses, games, and/or ODAs (self-contained and reusable digital objects) for individual sale, subscription-based access, or free access, which allow for autonomous student learning.

Tabela 4. EdTechs by type of technology

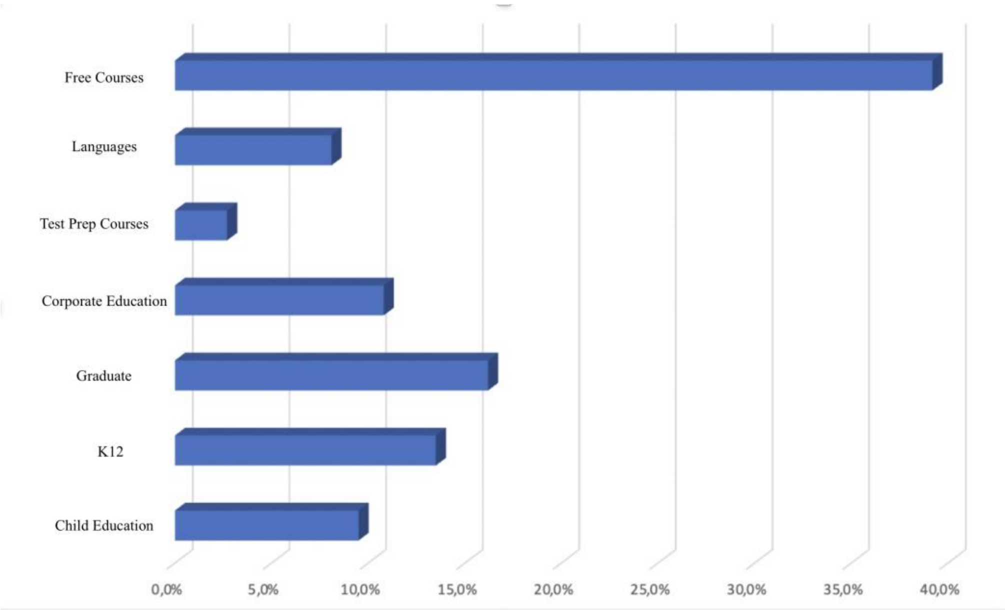
Technology type	**Nº**	**%**
Digital Learning Object (DLO)	21	3,7%
Educational Game	27	4,8%
Online Course	22	3,9%
Administrative-Financial Management Support Tool	23	4,1%
Pedagogical Management Support Tool	31	5,5%
Student Assessment Tool	53	9,4%
Curriculum Management Tool	2	0,4%
Authoring Tool	6	1,1%
Classroom Support Tool	5	0,9%
Collaboration Tool	5	0,9%
Tutoring Tool	22	3,9%
Educational Management System (EMS)	25	4,4%
Classroom Management System	-	-
Virtual Learning Environment (VLE)	31	5,5%
Educational Platform	24	4,2%
Adaptive Educational Platform	17	3%
Online Content Offering Platform	165	29,2%
Digital Repository	3	0,5%
Maker Tool	13	2,3%
Educational Hardware	3	0,5%
Other Products or Services	68	12%

Source: https://abstartups.com.br/wp-content/uploads/2021/04/M2020_edtechs.pdf

This data shows that the vast majority of EdTechs are focused on promoting knowledge and offering courses for people's complementary education, according to the BRAZILIAN STARTUP ASSOCIATION, 2020.

These same EdTechs that are focused on providing content for the complementary education of professionals can also be segmented by their actions and separated by the types of markets in which they operate, as observed in Graph 1 (BRAZILIAN STARTUP ASSOCIATION, 2020).

Graphic 1. EdTechs by market segment



Source: https://abstartups.com.br/wp-content/uploads/2021/04/M2020_edtechs.pdf

This segmentation showed that the vast majority of EdTechs are focused on the market of Free Courses, where they seek to bring new competencies and skills to those who consume them, in short periods of time, allowing them to be quickly applied in the workplace.

Therefore, it became relevant to evaluate the percentage of EdTechs that offer courses that promote the competencies demanded by the market. Since the highest concentration of EdTechs is in the Southeast region (58.7%) according to the BRAZILIAN ASSOCIATION OF STARPUS, 2020, the represented data was an analysis of EdTechs only from this region and is described in table 5. All 40 EdTechs from the states of Espirito Santo, Minas Gerais, Rio de Janeiro, and São Paulo, listed in the study, were analysed.

Table 5. Percentage of EdTechs that offer competency-based courses

Competencies	**% of EdTechs**
Cognitive Skills: Cognitive flexibility, Logical reasoning, Problem sensitivity, Mathematical reasoning, Visualization	40%
Creativity	50%
Reproduce simple knowledges	58%
Entrepreneurship	53%
Innovation	50%
Physical skills: Physical strength, Manual and precision dexterity	0%
Healthy physical	0%
Content Competencies, Active learning, Oral expression, Reading comprehension, Written expression, ICT literacy	53%
Interaction with other areas of knowledge	58%
Learning	48%
Communication	50%
Process Competencies: Active listening, Critical thinking, Self-monitoring and monitoring of others	55%
Social Competencies: Team coordination, Emotional intelligence, Negotiation, Persuasion, Service orientation, People management	48%
Multidisciplinary teamwork	50%
Social and Moral Responsibility	38%

Independency	60%
Systemic Competencies: Judgment and decision making, Systemic analysis	58%
Complex problem solving competencies: Complex problem solving	55%
Resource management Competencies: Financial resources management, Material resources management, People management, Time management	58%
Sustainable development and sustainability	38%
Technical Competencies: Equipment repair and maintenance, Equipment control and operation, Programming, Quality control	100%
Technical knowledge	100%

Source: Authors

These data have shown that currently, the majority of EdTechs can address the gap in the development of cross-functional skills demanded by the market. It is noteworthy that in virtually all competencies, at least 50% of the EdTechs in the analysed region offer courses for their development.

4 Conclusion

The data analyzed in this article suggests that there is currently a great availability of content that can meet the need for the development of cross-cutting skills demanded by the market. This high availability allows engineering professionals at all levels of seniority to continuously advance their education and development, thus enabling the market to have a greater number of more prepared professionals to perform the required functions. However, this does not exempt universities from the responsibility of developing, updating, and transforming themselves to provide an increasingly complete education for engineering professionals.

Due to the high demand for professionals to become more relevant and adapt to new requirements, the market has moved faster than universities to fill this gap, allowing for economic development and, most importantly, greater capacity-building for professionals promoting innovation and the advancement of the engineering field.

5 References

AIRES, R. W. A. et al. Educação Corporativa como ferramenta para estimular a inovação nas organizações: uma revisão de literatura. In:, 13º CONGRESSO BRASILEIRO DE GESTÃO DO CONHECIMENTO: São Paulo., 2016.

AHMED, F. et al., Soft Skills and Software Development: A Reflection from Software Industry. International Journal of Information Processing and Management (IJIPM), 4 (3),171-191, 2013.

ANDRADE, L. S. C.; A Influência das Soft Skillsna Atuação do Gestor:A Percepção dos Profissionais de Gestão de Pessoas. Dissertação de Mestrado Executivo em Gestão de Empresarial (Escola de Administração Pública e de Empresas da Fundação Getúlio Vargas). Rio de Janeiro, 2016. Disponível em: https://bibliotecadigital.fgv.br/dspace/handle/10438/17711. Acesso em:16 dez. de 2022.

ASSUNÇÃO, B. Y.; GOULART, B. I. Professional training or competencies for the future? Future studies Research Journal: Trends and Strategies, São Paulo, v. 8, nº 1, 175-208, 2016.

BANCO MUNDIAL. Competências e Empregos: uma agenda para a juventude. Brazil, p. 39, 2018. Disponível em https://documents1.worldbank.org/curated/en/953891520403854615/pdf/123968-WP-PUBLIC-PORTUGUESE-P156683-CompetenciaseEmpregosUmaAgendaparaaJuventude.pdf . Acesso em 27 mar. 2022.

BECKER Fernando. Educação e construção do conhecimento. 2 ed. Porto Alegre: Penso, 2012.

CAMPOS L. B. P. et al. Entrepreneurial and Engineering Education - a twofer proposal. In: 9TH INTERNATIONAL SYMPOSIUM ON PROJECT APPROACHES IN ENGINEERING EDUCATION (PAEE) 15th Active Learning in Engineering Education Workshop (ALE), 2018, Brasília. Anais. Brasília, 2018.

CARVALHO, Tatiane Augusta Godinho; TONINI, Adriana Maria. Desenvolvimento tecnológico e formação de competências na educação em engenharia. Revista de Ensino de Engenharia, v. 36, n. 1, p. 85–9, 2017.

CHEN, Guojin., ZHAN, J Jianhui. Study on training system and continuous improving mechanism for mechanical engineering. The Open Mechanical Engineering Journal, 9, 7-14, 2015.

CONFEDERAÇÃO NACIONAL DA INDÚSTRIA (CNI). Desafios para a indústria 4.0 no Brasil. Distrito Federal: Brasília. Disponível em https://www.portaldaindustria.com.br/publicacoes/2016/8/desafios-para-industria-40-no-brasil/. Acesso em 20 de mar 2022.

COSTA, N. A Importância das Competências Transversais (Soft Skills) na Formação do Engenheiro. Projeto de Monografia (Universidade de São Paulo). São Paulo, 2015. Disponível em: https://sistemas.eel.usp.br/bibliotecas/monografias/2015/MIQ15031.pdf. Acesso em: 04 jan de 2023.

EDTECHS. Associação Brasileira de Starpus. Disponível em https://abstartups.com.br/wp-content/uploads/2021/04/M2020_edtechs.pdf. Acesso em 23 de mar 2022.

EROL, S., et al. Tangible Industry 4.0: a scenario-based approach to learning for the future of production. Procedia CiRp, 54, 13-18, 2016.

FREITAS, Ellen Camila de. Inovação em educação e sua influência nos modelos tradicionais de ensino superior. 2017. 111 f. Dissertação de Mestrado em Administração de Empresas – Escola de Administração de Empresas, Fundação Getúlio Vargas, São Paulo, 2017. Disponível em: http://bibliotecadigital.fgv.br/dspace/handle/10438/18565. Acesso em 02 de jul de 2021.

GARBIE Ibrahim H. Incorporating Sustainability/Sustainable Development Concepts in Teaching Industrial Systems Design Courses. Procedia Manufacturing, 8, 417-423, 2017.

HECKLAU F. et al. Holistic approach for human resource management in Industry 4.0. Procedia Cirp, 54, 1-6, 2016.

LIMA, R. M. et al. Defining the Industrial and Engineering Management Professional Profile: a longitudinal study based on job offers. Production Journal,27. doi: 10.1590/0103-6513.229916, 2017.

MORÁN José Manuel. Mudando a educação com metodologias ativas. Disponível em: http://www2.eca.usp.br/moran/wp-content/uploads/2013/12/mudando_moran.pdf. Acesso em 03 de mar de 2022.

MATTASOGLIO NETO Octavio, SOSTER Tatiana Sansone. Inovação Acadêmica e Aprendizagem Ativa. Disponível em https://blog.lyceum.com.br/livro-inovacao-academica-e-aprendizagem-ativa/. Acesso em 20 de fev de 2022.

NETO MENDONÇA O. R. de, VIEIRA A.M., ANTUNES M. T. P. Industrialização da educação, edtech e prática docente. EccoS – Rev. Cient., São Paulo, n. 47, set./dez.; p. 149-170, 2018.

PENHAKI, Juliana de Rezende. Soft skills na indústria 4.0. 2019, 115f. Dissertação de Mestrado em Tecnologia e Sociedade. Universidade Tecnológica Federal do Paraná. Curitiba, 2019.

PENSIN, Daniela Pederiva; NIKOLAI, Dirciane. A inovação e a prática pedagógica no contexto da educação superior. Unoesc & Ciência – ACHS, Joaçaba, v. 4, n. 1, 31-54, 2013.

PIAGET, J. A Construção do Real na Criança. Trad. Álvaro Cabral. Rio de Janeiro:
Zahar, 1970.

RODRIGUES Adenir Carvalho, SOUSA Nilcélio Sacramento. Escola, passado e presente: mudanças sociais e novas exigências para os professores. Disponível em: https://educere.bruc.com.br/arquivo/pdf2017/23919_12915.pdf. Acesso em 25 de fev de 2022.

RUTZ K. P. et al. Avaliação da aprendizagem: pressupostos teóricos e problematizações. Revista Cocar. ISSN: 2237-0315; V.15 N.31/ p.1-20, 2021.

ROBLES Marcel. M. Executive perceptions of the top 10 soft skills needed in today's workplace. Business Communication Quarterly, 75(4),453-465., 2012.

SAVIANI, D. Trabalho e educação: fundamentos ontológicos e históricos. Revista
Brasileira de Educação, [s.l.], v.12, n.34, p.152-180, 2007. Disponível em:
http://www.scielo.br/pdf/rbedu/v12n34/a12v1234.pdf. Acesso em: 12 jan. 2023.

SCHWAB Klaus.. The Fourth Industrial Revolution: what it means, how to respond. Disponível em https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/ Acesso em 10 de mar 2022.

SILVA B. X. F., Neto V. C., Gritti N. H. S. SOFT SKILLS: toward success in a professional world. Interface Tecnológica. DOI: 10.31510/infa.v17i1.797. v. 17, n 1, 2020.

SORKO Sabrina Romina, IRSA W Wolfram. Engineering education - Status quo in Austria in comparison with the academic field of business education. Turkish Online Journal of Educational Technology, 890-894, 2016.

SOUZA A. S. et al., Forjando empreendedores: o papel dos engenheiros sem fronteiras. In: XXXIX ENCONTRO NACIONAL DE ENGENHARIA DE PRODUÇÃO: "OS DESAFIOS DA ENGENHARIA DE PRODUÇÃO PARA UMA GESTÃO INOVADORA DA LOGÍSTICA E OPERAÇÕES" Santos, São Paulo, Brasil, 2019.

STURM C.H., et al. Mapeamento e análise de desempenho da graduação e da pós-graduação em engenharia de produção no Brasil. Gestão & Produção, v. 22, n. 1, p. 149–163, 2015.

TÄKS M.et al. Engineering Students' Experiences in Studying Entrepreneurship. Journal of Engineering Education, 4 (103), 573-598, 2014.

TOEBE, Iris Cristina Datsch. Políticas públicas para integração de tecnologias educacionais na formação inicial de professores. 2016. 170f. Dissertação de Mestrado em Educação – Universidade Federal de Santa Maria, Santa Maria, 2016.

VIDAL Odaléa Feitosa, MERCADO Luís Paulo Leopoldo. Integraçãodas Tecnologias Digitais da Informaçãoe Comunicação em Práticas Pedagógicas Inovadoras no Ensino Superior. Rev. Diálogo Educ., Curitiba, v. 20, n. 65, p. 722-749, 2020.

VORONINA, Mariana. V., MOROZ, Olga. N. A Substantiation of foresight research of development strategy of descriptive geometry, engineering geometry and computer graphics departments on the basis of industrial 4.0 ideology. Man In India, 97(3), 375-389, 2017.

ZANETTI Micheli et al., Facelera: desenvolvendo habilidades corporativas, sociais e tecnológicas em discentes dos cursos de engenharias. Repae, São Paulo, ISSN: 2447-6129. v. 7, n.3, p. 28-50, 2021.

WORLD ECONOMIC FORUM. The future of Jobs: employment, skills and workforce strategy for the fourth revolution. Global Challenge Insight Report, 2016.

A PBL experience with second-year students of Industrial Engineering

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Abstract

In the last years, teaching methods significantly evolved. Instead of traditional teaching, where the professor is the primary source of knowledge, nowadays, student-centered approaches, where they actively participate in their learning, have been increasingly used. These methods allow increasing the students' motivation, interest, and engagement in the learning process. There are different ways of implementing active learning, for instance, through group work, case studies, debates, and problem-based learning, among others.

In the present work, a case study of an active learning approach is presented. A new curricular unit was created and integrated into the Bachelor in Industrial Engineering of the University of Minho in the academic year of 2021/2022. This combined four different curricular units, Complements of Applied Statistics, Numerical Methods, Information Systems and Technology, and Operational Research and Optimization, that are already part of the study plan. The main aim of this initiative was to provide students with a learning environment that encourages investigation, critical thinking, teamwork, problem-solving skills, and hands-on activities. This way, students have a more holistic and integrated understanding of each engineering subject and its relevance to the real world. The classes consisted of active discussions between the professor and students about the challenges and doubts they have in the work development and sharing ideas on how they can accomplish it. Each group selected a theme and obtained real databases about the topic from the internet. Then, they had to treat the data and combine the different subjects. In general, the outputs were very encouraging and, in some cases, surpassed expectations. Excellent works were developed, and it was thrilling to see how bachelor students embraced this challenge and were able to work on real data in such a short space of time. Furthermore, students found this learning initiative more engaging and interesting than traditional teaching. From the professors' point of view, this curricular unit was successful as it brought good outputs and interdisciplinary discussions among both students and professors.

Keywords: Active learning; team-based learning; problem-solving; students' engagement

1 Introduction

Teaching engineering can be a challenging task as it requires a balance of theoretical knowledge and practical skills. For many years, the lecture teaching approach was the primary teaching method in education. However, this often involves passive learning, with limited interaction and creativity, and exams are the main assessment tool, which promotes learning by memorization rather than understanding (Woschank & Pacher, 2020; Yeung et al., 2023). In contrast, active learning approaches allow students to be more involved in the learning process and these have shown to be more effective in promoting long-term retention of knowledge, critical thinking, motivation, and class attendance (Marja & Suvi, 2021; Okoro & Hedima, 2022; Prince, 2004; Saravanan et al., 2021; Slavich & Zimbardo, 2012). Problem-based learning (Maia & Dos Santos, 2022), collaborative learning (Chytas et al., 2022; Miller et al., 2017; Silva et al., 2022), experiential learning (V. Carvalho et al., 2021; V. M. Carvalho et al., 2022), role-play (Baruch, 2006), peer instruction (Tullis & Goldstone, 2020), flipped classroom (Foster & Stagl, 2018; McLaughlin et al., 2014; Roehl et al., 2013), and gamification (Hammad et al., 2022), are some examples of active learning approaches that can enhance engineering education and better prepare students for real-world challenges. For instance, Sharma and co-workers (Sharma & Mantri, 2020) proposed a new approach to learning science in engineering education by incorporating disruptive technology and active learning, such as problem-based learning, inquiry-based learning, and project-based learning. The authors showed that by combining both approaches the effectiveness of science education and the preparation of students for the rapidly changing technological landscape can be enhanced. Another example was proposed by Lopéz Fernandez et al. (López-Fernández et al., 2020). The authors implemented a Challenge-Based Learning approach in aerospace engineering education using the ESA Concurrent Engineering Challenge at the Technical University of Madrid. In brief, this consisted in a week-long intensive design project where multidisciplinary student teams worked together to develop a space mission concept. It was found that students improved their technical and soft skills, increased their motivation and interest in aerospace engineering, and presented higher levels of satisfaction with their learning experience. On the other hand, Lorico et al. (Lapitan et al., 2023) designed, implemented and evaluated an online flipped classroom with a collaborative learning model in an undergraduate chemical engineering course. This involved online videos as pre-class tasks and conducting collaborative learning activities in the classroom. This approach was found to be effective in improving students' academic achievements, as evidenced by increased course grades and higher levels of student engagement and satisfaction. Similarly, Howel (Howell, 2021) explored the benefits of active learning, reflective practices, and flipped classroom pedagogies in engaging students in education for sustainable development by applying pre-class preparation, in-class activities, and post-class follow-up activities. Incorporating these pedagogies in education for sustainable development can lead to more effective and impactful learning outcomes. On the other hand, Espey (Espey, 2022) studied the variation in individual engagement in team-based learning and its impact on final exam performance. The results showed a significant variation in individual engagement within the teams and a positive correlation between engagement and final exam performance. The study also identified several factors that influence individual engagement, such as prior academic achievement, personality traits, and group dynamics. Chilukuri (Chilukuri, 2020) proposed a novel framework to improve student's learning outcomes and showed how this can be applied in different engineering courses. This comprises five stages, defining course outcomes, designing active learning activities, selecting appropriate assessment methods, implementing active learning activities, and evaluating student learning outcomes.

Bearing in mind the benefits of active learning approaches, herein, a learning experience with bachelor students of Industrial Engineering of the University of Minho through a new curricular unit (CU) is presented focusing on the quantitative methods components.

2 The new "Integrated Project"

2.1 Scope and objectives of the CU

The CU entitled "Integrated Project" is already part of the Bachelor in Industrial Engineering of the University of Minho in the first year, in the first semester, and also in the third year, in the second semester. The purpose of introducing this CU in the study plan of the course was to reduce the number of assignments carried out by students, by combining different CUs of the semester in a single task (Alves et al., 2019; Alves & Soares, 2019; Leão et al., 2022). However, the implementation of this CU in the 2nd year of the course, took place for the first time, in the academic year of 2021/2022, and comprises four different CUs of the 2nd semester of the 2nd year. These are Complements of Applied Statistics, Operational Research and Optimization, Numerical Methods, and Information Systems and Technology.

The main teaching objectives of the project are the following:

- Develop technical skills by applying the syllabus contents of the CUs participating in the context of the project.
- Develop transversal skills in a team-based environment.

In general, the project intended to constitute a challenge for students in dealing with real data, requiring learning skills from the CUs involved. The integration of the contents of the CUs and their practical application in an interdisciplinary project provides students with a more solid learning experience. Furthermore, the execution of the project poses several challenges to students in terms of project management, task planning, meeting deadlines, communication, and teamwork.

The skills that students must acquire with the integrated project include transversal skills and several specific skills of the CUs that integrate it, which are:

- Develop an interdisciplinary team project;
- Apply the contents of the curricular units in the context of the project;
- Apply statistical data analysis techniques to real problems;
- Solve multidisciplinary industrial engineering problems involving real data;
- Database manipulation and management tools;
- Implement software for data manipulation and analysis;
- Develop teamwork skills in a project environment;

In general, this CU worked as an informal working environment where the professors could follow up and help the students. Students could openly discuss with the professor the work progress and challenges they are facing and also deepen their knowledge of solving problems in a real context.

2.2 Proposed topics for teamwork

To conduct the teamwork, the students divided themselves into 7 groups of 10-12 students each. After the groups were created, students had to choose a theme. Within the scope of the project, different topics of interest to the students were proposed:

- Forest fires – Causes and conditions that favor the emergence of forest fires; consequences in economic and environmental terms and loss of human life; prevention; combat; location of installations and means of combat.
- Energy – Thermal comfort; efficiency; energy markets; construction materials; location of facilities (e.g., wind and solar farms, other).
- Sports – Performance; health; transfer market; entertainment; location of sports facilities.

After deciding on the work topic, students had to collect, prepare, and analyze the data.

In the development of the project work, it was suggested the use of real data that could be obtained from databases/data repositories (Table 1).

Table 1. List of possible databases provided to students

Databases
Portal of the National Statistics Institute (https://www.ine.pt)
Eurostat (https://ec.europa.eu/eurostat)
Official European data portal (https://data.europa.eu/pt)
UCI - Machine Learning Repository (https://archive.ics.uci.edu/ml/index.php)

Kaggle (https://www.kaggle.com)
Google dataset search (https://datasetsearch.research.google.com)
Datahub (https://datahub.io)
Our World in Data (www.ourworldindata.org)
Pordata - Contemporary Portugal database (https://www.pordata.pt)

2.3 Expected outcomes in each module of the CU

As previously mentioned, despite the project involving four CUs, the present work focuses on the Complements of Applied Statistics and Numerical Methods modules. In Table 2, the expected outcomes of each are presented.

Table 2. Expected outcomes of Complements of Applied Statistics and Numerical Methods modules.

Expected outcomes	
Complements of Applied Statistics	**Numerical Methods**
Prepare and organize data to perform quantitative analysis.	Develop numerical skills in the analysis and evaluation of systems.
Analyze variables separately and relationships between variables / multivariate analysis.	Use a set of techniques to model and evaluate physical problems.
Perform statistical inference, using confidence intervals and statistical tests.	Use computational data analysis tools.
Apply the most appropriate statistical tests (parametric and non-parametric)	Compare different methods in solving numerical problems.
Analyze and verify assumptions for the application of statistical methods.	Develop capabilities for evaluating and criticizing results.
Apply regression models to estimate variables, assess the goodness of fit of the models and assess correlations.	
Clearly, concisely and rigorously communicate data analysis results.	
Use data analysis software: Python (e.g., NumPy, SciPy, Pandas), R or SPSS.	

2.4 Outcomes

In this section, some of the outcomes obtained by students are presented. In the Numerical Methods module, the idea was to use linear models both polynomial and non-polynomial by resorting to the curve fit tool available in Matlab software. Regarding the Complements of Applied Statistics component, students used the SPSS software to conduct the statistical analysis, both qualitative and quantitative. One of the groups performed the analysis of the forest fires. In one of the analyses conducted, the students evaluated the number of forest fires per city in the Braga district in 2011 and 2020, and Cabeceiras de Basto and Vila Nova de Famalicão stood out in both cases. Then, the students tried to approximate the data through a third-degree polynomial from 2001 and 2020. It was found a reduction in the mean number which was excellent to observe. Another group evaluated the energetic situation in Portugal. Firstly, the students showed graphically the relationship between the consumption and production of energy in Portugal over the years. Students observed that between 2018 and 2020 consumption was lower than production, portraying a perfect situation for the country, as it becomes self-sufficient and capable of exporting or storing energy. While, in 2022, the consumption exceeded the production, which caused an increase in energetic importation. Besides, the students approximated the data of energy consumption-production in the year 2020 and observed that during April and May, the curve is above the zero value, which shows that the consumption was higher than production. This may be related to the confinement due to the pandemic of COVID-19. Another group also evaluated the energy consumption in Portugal but only for the years 2021 and part of 2022. The findings showed that the electrical power consumed is greater between 8 pm and 10 pm, which can be related to dinner time and leisure. The students also estimated the polynomial function that best describes energy consumption in 2021. A peak in January was notorious, possibly explained by the great use of heating sources, decreasing until April, when it reaches a minimum value. In November and December, a significant increase in consumption was registered. These results may also be related to the new confinement at the beginning of the year 2021. On the other hand, this means that it could be useful to forecast energy demand in atypical situations.

2.5 Assessment methodology

The individual rating of each student depended on the final rating obtained by the team to which it belonged and on the combined results of the student's self-assessment and the team's heterogeneity assessment. These assessments are mandatory and have been carried out at different key times between the beginning and end of the semester. The assessment model was common and consisted of five different levels of assessment on a scale of 1 to 20 (higher values represent better assessment): attendance at meetings, dedicated work effort, original contributions, interpersonal relationships, and fulfillment of deadlines. Students already knew and were familiar with this peer-assessment model, which is similar to the one used in the 1st year project. More details can be found in (Alves et al., 2018).

The final team classification in the integrated project results from the weighted average of the classifications obtained in the different evaluation elements (mid-term report and poster presentation, final report, and final presentation and discussion). Each assessment element had different weights in the calculation of the team's final classification. The applied evaluation criteria are presented in Table 3.

Table 3. Evaluation criteria for the mid-term and final report and the oral presentations.

Evaluation criteria for the mid-term and final report	**Evaluation criteria for the oral presentations**
Adequacy of the work to the objectives	Structure of the presentation
Report structure	Presentation and organization
Presentation and organization	Theoretical foundation and rigor
Theoretical foundation and rigor	Communication capacity
Synthesis capacity	Capacity for reflection and critical analysis
Capacity for reflection and critical analysis	Clarity of exposition and language correction
Clarity and correction of language	Presentation time fullfiled
Compliance with deadlines	
Respect for academic production rules	

The creation of a mid-term report and poster presentation intended to ensure that the work is being carried out according to plan and also to identify any difficulties. The poster session allowed the teams to present the work carried out at that time and to interact, simultaneously, with the professors of the different CUs to clarify doubts and solve difficulties that may affect the progress of the work.

In addition to the assessment of the work, control points along the semester were created in order to follow the progress of work, ensuring that tasks are carried out at a good pace and that project objectives are achieved.

It should be also noted that the final classification of students in each CU participating in the project results only from the evaluation methodology of each of these CUs.

3 Conclusions and Future Perspectives

In the present work, a team-based learning experience with bachelor Industrial Engineering students at the University of Minho was presented. This emerged from a new CU entitled, "Integrated Project" which integrates the knowledge of several CUs of the semester in the resolution of problems involving data. Given its multidisciplinary nature, students developed technical skills and soft skills. Technical skills resulted from the application of the contents of the semester's CUs to solve an industrial engineering problem involving data. The transversal skills were achieved in the development of the project in a team and presentation of the results of the work, which required organization, time management, decision-making, creativity, critical thinking, autonomy, responsibility, leadership, problem-solving, and written and oral communication.

Given the success of this novel CU, this was implemented in the following academic year. In a future study, both the students and professors' perspectives will be evaluated through questionnaires.

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5 References

Alves, A. C., Moreira, F., & Leao, C. P. (2018). Peer assessment in PBL: Does gender matter? 2017 International Conference on Engineering, Technology and Innovation: Engineering, Technology and Innovation Management Beyond 2020: New Challenges, New Approaches, ICE/ITMC 2017 - Proceedings, 2018-Janua, 1357–1361. https://doi.org/10.1109/ICE.2017.8280039

Alves, A. C., Moreira, F., Leão, C. P., Pereira, A. C., Pereira-Lima, S. M. M. A., Malheiro, M. T., Lopes, S. O., & Oliveira, S. M. C. (2019). Industrial engineering and management PBL implementation: An effortless experience? International Symposium on Project Approaches in Engineering Education, 117–127.

Alves, A. C., & Soares, F. (2019). Interdisciplinary contents integration and key competences developed in a project work of Industrial Engineering and Management third year. International Symposium on Project Approaches in Engineering Education, 21–30.

Baruch, Y. (2006). Role-play teaching: Acting in the classroom. Management Learning, 37(1), 43–61. https://doi.org/10.1177/1350507606060980

Carvalho, V. M., Rodrigues, C. S., Lima, R. A., Minas, G., & Teixeira, S. F. C. F. (2022). i9MASKS Project: A Learning-by-Doing Summer Experience With Engineering Students. In A. C. Alves & N. van Hattum-Janssen (Eds.), Training Engineering Students for Modern Technological Advancement. IGI Global. https://doi.org/10.4018/978-1-7998-8816-1

Carvalho, V., Teixeira, S., Lima, R. A., Minas, G., & Rodrigues, C. (2021). Learning science during summer vacations and its effects on attitude and anxiety towards research. International Conference on Active Learning in Engineering Education.

Chilukuri, K. C. (2020). A novel framework for active learning in engineering education mapped to course outcomes. Procedia Computer Science, 172, 28–33. https://doi.org/10.1016/j.procs.2020.05.004

Chytas, D., Noussios, G., Paraskevas, G., Demesticha, T., Protogerou, V., & Salmas, M. (2022). Incorporation of team-based learning in the cadaveric anatomy laboratory: An overview. Morphologie, xxxx. https://doi.org/10.1016/j.morpho.2022.09.001

Espey, M. (2022). Variation in individual engagement in team-based learning and final exam performance. International Review of Economics Education, 41(September), 100251. https://doi.org/10.1016/j.iree.2022.100251

Foster, G., & Stagl, S. (2018). Design, implementation, and evaluation of an inverted (flipped) classroom model economics for sustainable education course. Journal of Cleaner Production, 183, 1323–1336. https://doi.org/10.1016/j.jclepro.2018.02.177

Hammad, S., Graham, T., Dimitriadis, C., & Taylor, A. (2022). Effects of a successful mathematics classroom framework on students' mathematics self-efficacy, motivation, and achievement: a case study with freshmen students at a university foundation programme in Kuwait. International Journal of Mathematical Education in Science and Technology, 53(6), 1502–1527. https://doi.org/10.1080/0020739X.2020.1831091

Howell, R. A. (2021). Engaging students in education for sustainable development: The benefits of active learning, reflective practices and flipped classroom pedagogies. Journal of Cleaner Production, 325(June), 129318. https://doi.org/10.1016/j.jclepro.2021.129318

Lapitan, L. D., Chan, A. L. A., Sabarillo, N. S., Sumalinog, D. A. G., & Diaz, J. M. S. (2023). Design, implementation, and evaluation of an online flipped classroom with collaborative learning model in an undergraduate chemical engineering course. Education for Chemical Engineers, 43(April 2022), 58–72. https://doi.org/10.1016/j.ece.2023.01.007

Leão, C. P., Abreu, M. F., Alves, A. C., & Fernandes, S. (2022). PBL tutoring dynamics in first-year of Industrial Engineering and Management Program. International Symposium on Project Approaches in Engineering Education, 212–219. https://doi.org/10.5281/zenodo.7061886

López-Fernández, D., Salgado Sánchez, P., Fernández, J., Tinao, I., & Lapuerta, V. (2020). Challenge-Based Learning in Aerospace Engineering Education: The ESA Concurrent Engineering Challenge at the Technical University of Madrid. Acta Astronautica, 171(December 2019), 369–377. https://doi.org/10.1016/j.actaastro.2020.03.027

Maia, D., & Dos Santos, S. C. (2022). Monitoring Students' Professional Competencies in PBL: A Proposal Founded on Constructive Alignment and Supported by AI Technologies. Proceedings - Frontiers in Education Conference, FIE, 2022-Octob. https://doi.org/10.1109/FIE56618.2022.9962459

Marja, S. L., & Suvi, A. (2021). Cultural competence learning of the health care students using simulation pedagogy: An integrative review. In Nurse Education in Practice (Vol. 52). Elsevier Ltd. https://doi.org/10.1016/j.nepr.2021.103044

McLaughlin, J. E., Roth, M. T., Glatt, D. M., Gharkholonarehe, N., Davidson, C. A., Griffin, L. M., Esserman, D. A., & Mumper, R. J. (2014). The flipped classroom: A course redesign to foster learning and engagement in a health professions school. Academic Medicine, 89(2), 236–243. https://doi.org/10.1097/ACM.0000000000000086

Miller, D. M., Khalil, K., Iskaros, O., & Van Amburgh, J. A. (2017). Professional and pre-professional pharmacy students' perceptions of team based learning (TBL) at a private research-intensive university. Currents in Pharmacy Teaching and Learning, 9(4), 666–670. https://doi.org/10.1016/j.cptl.2017.03.001

Okoro, R. N., & Hedima, E. W. (2022). Undergraduate pharmacy students' perceived learning using a team-based debate approach. Currents in Pharmacy Teaching and Learning, 14(5), 612–617. https://doi.org/10.1016/j.cptl.2022.04.017

Prince, M. (2004). Does active learning work? A review of the research. Journal of Engineering Education, 93(3), 223–231. https://doi.org/10.1002/j.2168-9830.2004.tb00809.x

Roehl, A., Reddy, S. L., & Shannon, G. J. (2013). The Flipped Classroom: An Opportunity To Engage Millennial Students Through Active Learning Strategies. Journal of Family & Consumer Sciences, 105(2), 44–49. https://doi.org/10.14307/jfcs105.2.12

Saravanan, S., Mahesh, V., Kumar, D. G., & Kshatri, S. S. (2021). Improving student's learning with efficient learning techniques: A case study of first year basic electrical engineering course. Materials Today: Proceedings. https://doi.org/https://doi.org/10.1016/j.matpr.2021.02.784

Sharma, B., & Mantri, A. (2020). Assimilating disruptive technology: A new approach of learning science in engineering education. Procedia Computer Science, 172(2019), 915–921. https://doi.org/10.1016/j.procs.2020.05.132

Silva, E. C. e., Lino-Neto, T., Ribeiro, E., Rocha, M., & Costa, M. J. (2022). Going virtual and going wide: comparing Team-Based Learning in-class versus online and across disciplines. Education and Information Technologies, 27(2), 2311–2329. https://doi.org/10.1007/s10639-021-10683-0

Slavich, G. M., & Zimbardo, P. G. (2012). Transformational Teaching: Theoretical Underpinnings, Basic Principles, and Core Methods. Educational Psychology Review, 24(4), 569–608. https://doi.org/10.1007/s10648-012-9199-6

Tullis, J. G., & Goldstone, R. L. (2020). Why does peer instruction benefit student learning? Cognitive Research: Principles and Implications, 5(1). https://doi.org/10.1186/s41235-020-00218-5

Woschank, M., & Pacher, C. (2020). Teaching and learning methods in the context of industrial logistics engineering education. Procedia Manufacturing, 51(2019), 1709–1716. https://doi.org/10.1016/j.promfg.2020.10.238

Yeung, M. M.-Y., Yuen, J. W.-M., Chen, J. M.-T., & Lam, K. K.-L. (2023). The efficacy of team-based learning in developing the generic capability of problem-solving ability and critical thinking skills in nursing education: A systematic review. Nurse Education Today, 122(September 2022), 105704. https://doi.org/10.1016/j.nedt.2022.105704

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PAEE/ALE’2023 Workshops and Hands-on sessions

Submissions accepted for the PAEE/ALE’2023 hands-on sessions.

“Ethics pills”: Including ethics in any engineering course, right now, right here

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Abstract

Although it is widely agreed that the ethical perspective must be present in engineering studies, most engineering degrees do not have an ethics in engineering course. In the proposed hands-on session participants will explore the possibility of adding an ethics perspective to any course. We will discuss how to select topics of interest related (or not) to the course content and how to include them within the course schedule.

Keywords: Active Learning; Engineering Education; Conference Information; Project Approaches.

1 Introduction

It is assumed that promoting the reflection about ethical issues, as well as any other generic competence, is essential in the learning process of the future engineers. Notwithstanding, in many cases the relevance of technical knowledge leaves no room in the syllabus for specific development of transverse competences. Having no room for ethics in technical courses is cited (Walczac et al, 2010, Davis, 2006) as one of the main institutional obstacles. As an example of this situation, in the telecommunication engineering degree developed at the University of Alicante, one of the objectives that can be read in it states “the ethical responsibility of engineering work” as a competence to be obtained by students. However, there is no course, neither compulsory nor elective, about ethical issues. The study conducted by Walczac et al (2006) states five common themes between the obstacles to integrating ethics into the curriculum:

- The curriculum is already full, and there is little room for ethics education.
- Faculty lack adequate training for teaching ethics.
- There are too few incentives to incorporate ethics into the curriculum.
- Policies about academic dishonesty are inconsistent.
- Institutional growth in taxing existing resources.

There are several ways suggested in the literature about how to introduce ethics in engineering education. A systematic approach to introduce what to teach and how to teach it is presented by Li and Fu (2010).

An interesting fact is that students explicitly want to discuss about ethics and critical thinking in engineering and engineering education, as conclude in the Board of European Students of Technology Symposium (BEST, 2006). One of the outcomes of this meeting is related with the problems that ethics courses use to have when included in engineering degrees:

Talking about the inclusion of ethics in current university education there are different situations:

- Complete specific course on ethics.
- Integrated in some other courses – based on the will of the teachers or part of the program of the course.
- The students are not taught ethics at all.

Even if ethics is taught in some universities, like in the first two cases, it can be problematic in some situations:

- The course is elective and not all the students are taking part because of the big number of courses they can choose.
- The material is extensively theoretical.
- Professors have no proper approach and make the course not attractive and tedious. The methods that are used are inappropriate.

It is relevant to listen to students' opinion to offer them a set of activities that will be received with the proper positive attitude. In this sense, some of their suggestions about how to include ethics in engineering curriculum include the following:

- The course should give a direction of thinking that would make people more aware of their actions. By introducing a certain level of criticism, automatic behaviour would be excluded from decision making.
- Students generally would like to have interaction among all the students that enrolled the course and the teacher. It is a way through which more ideas could come up and more sharing could exist.
- The course should include case studies, examples from real life, problem–solving methods. The course should represent a lot of examples from real life.
- Dynamic course: as the time is changing the material should also change. The technologies are changing, so the courses should take it into account.
- About the person(s) who will give the course there were more ideas:
  ◦ the person should have not just theoretical knowledge but also a practical background, the person should have experience as working as an engineer or as an option, special training on ethics.
  ◦ Cooperation among two persons: engineer who will be practical and philosopher who will be theoretical.

As a result of a previous study, table I include the most cited topics engineering students from the University of Alicante would like to have included in ethics sessions.

Table I. Topics to be included according to students' opinion.

	Topic	%
1	Acting in accordance with personal principles	25
2	Social/environmental impact of work	22
3	Personal attitude (confidence, personality, commitment...)	13
4	Fair labour market/labour intrusiveness	10
5	Economic considerations	10
6	Professionalism	10
7	Other unclassified aspects	10

2 Activities

The main idea of the hands-on session is to show participants how to include ethical issues in any course following (as much as possible) students' ideas about this kind of activities. Davis (2006) proposes using 'micro-insertion' as a way to put ethics into technical courses without substantial change in the course and in a way students appreciate. According to Harris et al. (1996) there is a widespread agreement that the best way to teach professional ethics is by using cases. Two modes that can be useful for treating cases are "drawing the line" and conflict cases. Attendants will be arranged in small groups making emphasis in forming teams with people with different background. The method, combining micro-insertion and case study (ethic pills), for incorporating ethics when specific courses are not available will be presented. The session will be organized as follows:

- Topic presentation.
- Warm-up activity.
- Group activities (ethics pills).
- Discussion.
- Conclusion.

3 Expected results

Session attendants will play students' role in the proposed activity. The most relevant results of the session will come after the discussion. It will be interesting to know if participants find the proposal interesting enough to use it by themselves and to listen to their comment to make the activity more interesting and productive.

4 References

BEST (2006). Ethics and sustainable development issues in engineering education. Board of European Students of Technology Symposium on Education report. Madrid 2006 (available online at https://static.best.eu.org/download/edu/Symposium_Madrid_Report.pdf, last accessed in April 2023).

Davis, M. (2006). Integrating ethics into technical courses: Micro-insertion. Science and Engineering Ehtics (2006) 12, 717-730.

Harris, C. E, Daves, M., Pritchard, M. S., Rabins, M. J. (1996), Engineering ethics: What? Why? How? and When?. Journal of Engineering Education, volume 85, Issue 2, April 1996, 93-96. https://doi.org/10.1002/j.2168-9830.1996.tb00216.x

Li, J., Fu, S. A (2012). Systematic Approach to Engineering Ethics Education. Sci Eng Ethics 18, 339–349 (2012). https://doi.org/10.1007/s11948-010-9249-8.

Walczak, K., Finelli, C., Holsapple, M., Sutkus, J., Harding, T. R. (2010). Institutional obstacles to integrating ethics into the curriculum and strategies for overcoming them. American Society for Engineering Education.

Haaukins: Cyber Security Training with Gamification

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Abstract

With increased digitalization, our societies have become more vulnerable to cyber-attacks, and we are already seeing both criminal groups and nation states being very active in the cyber domain. This calls for action in order to better protect our societies, companies, and people against these attacks. One of the main challenges with respect to this is the lack of skilled people -a gap that is expected to increase in the coming years. To increase the interest in cyber security among young people, and to increase the competence level among young people, Aalborg University together with a number of partners have developed the training platform Haaukins. It can easily be setup by teachers, who can select which challenges the students will work on - a typical session would contain around 10 challenges out of the 400 currently provided. The students are then presented with these challenges along with a virtual lab, which provides a closed and secure environment for working with cyber security. Upon solving challenges, the students can gain points and compete with their classmates. The workshop provides an overview of the platform, and then takes the participants through a typical training session which require no previous experience with computers, programing, or cyber security. The session consists of a short introduction to the platform, followed by a mix of short presentations, demonstrations, and independent work on challenges. After the session, a discussion on how the platform can be integrated in learning activities is facilitated. A particular focus in the discussion is how more diversity among the students can be achieved.

Keywords: Active Learning; Gamification; Cyber Security; Engineering Education.

1 Introduction

The number of cyber-attacks has been increasing during recent years. According to the Federal Bureau of Investigation (FBI, 2023) the losses from Internet related crimes has increased significantly during the last five years, hitting an all-time high in 2022 with $10.3 billion. The number of cases saw a small drop from 2021 to 2022, but still increased from 351,937 cases in 2018 go 800,944 cases in 2022. These numbers only reflect what is actually being reported, so the numbers could be significantly higher. Also, the numbers reflect only that of cybercrime and not state-sponsored activities such as cyber espionage and influencing decisions and opinions.

While new legislation, such as the Network and Information Security Directive 2 in the European Union, is on the way in order to increase the overall cyber security posture of companies and societies, one of the biggest problems remain: The Cyber Security Skill gap. It is expected that on a global scale there are currently missing 3,4 million cyber security professionals (ICS2, 2022).

Aalborg University has been a pioneer in Denmark when it comes to engaging more young people in cyber security. This is done through several projects funded by the Danish Industry Foundation, including Cyberskills (Cyberskills, 2023) and The Danish Cyber Security Championships (Cybermesterskaberne, 2023). The purpose of the projects is two-fold:

- To increase the competence level in cyber security among young people in Denmark.
- To attract more young people to choose an education and career within cyber security.

This reflects that there is a need both for increasing the general level of cyber security competences among all young people, and for increasing the number of cyber security professionals. The projects are also based on the philosophy that we need to both:

- Increase the interest in cyber security, by demonstrating it is important and interesting.
- Maintain the interest by creating communities and places where it is possible to cultivate the interest and learn more, both within and beyond the formal educational system.

The latter bullet also reflects the fact that it is of little help that people find cyber security interesting, if there is nowhere to go to learn more and maintain the interest.

In addition to these initiatives, other initiatives are targeting a more mature audience through e.g. continuing education and company specific trainings.

One of the most successful methods we have found across all target groups is to use gamification and the Capture The Flag format (Collins & Ford, 2023). The concept is that students/participants solve challenges in a closed and secure environment, and for every challenge receive a number of points that can be seen on a scoreboard. We have developed the Haaukins platform (Panum et al., 2019) to facilitate this in a manner where it is easy to setup and use, since everything of the environment can be accessed through a browser without requiring any software to be installed for the participants. It is possible to select challenges to fit the topic/level of the training, so it can be used for both very beginners pre high-school to cyber security professionals. Recent developments have focused on making it even easier for teachers without a technical background to use (Mennecozzi et al., 2021). This hands-on session will focus on how gamification and the Haaukins platform can be used for cyber security training at all levels, and the hands-on workshop will be complemented with discussions on didactical aspects, integration to other educational activities, and the gender balance issue. No prior knowledge of cyber security is needed in order to participate in the workshop.

2 Activities

The first 15 minutes of the workshop will be spent on a short introduction to cyber security, the concept of CTF and the Haaukins platform. Following this, the participants will go through a classical use of Haaukins in an educational setting, which includes 2 rounds of learnings and challenges. The topics chosen for this session will require no technical knowledge, and cover beginner challenges in "web security" and "passwords". Each round includes:

- Introduction to the topic and vulnerabilities (5 minutes).
- Solving challenges in small groups 2 by 2 (15 minutes).
- Discussing how these vulnerabilities can be mitigated (5 minutes).

Each participant should bring his/her own computer, but no special software is required. The participants will get a small-scale experience of how Haaukins is used in practice, and there will be a scoreboard with points specifically created for the workshop.

After this learning experience, a 5-minute presentation will be given on a current research project on how to create content and challenges that is more appealing to females.

The last 20 minutes are allocated to a joint plenum discussion. The points addressed here will be:

- The experience with using the platform, and reflections with respect to didactics.
- How Haaukins and CTF can be integrated into formal and informal learning activities.
- How Haaukins and CTF can be used to promote diversity in cyber security and attract more females to the field.

3 Expected results

The expected results of the workshop is three-fold:

- The participants will get inspiration and concrete didactical tools, which will enable them to implement elements of gamification in their own teaching practices, especially in terms of using the Capture The Flag concept.
- The participants will become familiar with the Haaukins platform, and learn how it can be used to implement the aforementioned elements of gamification.
- The participants will share reflections on the use of gamification in teaching with particular focus on cyber security. These reflections are useful in developing their own teaching strategies, but also in the further development of the Haaukins platform.

4 References

Cybermesterskaberne (2023). The Danish Cyber Security Championships website, https://cybermesterskaberne.dk.

Cyberskills (2023). Cyberskills website, https://cyberskills.dk.

Collins, J & Ford, V. Teaching by Practice: Shaping Secure Coding Mentalities through Cybersecurity CTFs. Journal of Cybersecurity Education, Research & Practice. Vol. 2022, No. 2 (2022). DOI 10.32727/8.2023.8.

FBI (2023). Federal Bureau of Investigation, Internet Crime Complaint Center: Internet Crime Report 2022. https://www.ic3.gov/Media/PDF/AnnualReport/2022_IC3Report.pdf.

ISC2 (2022). (ISC)2 Cybersecurity Workforce Study, https://www.isc2.org/-/media/ISC2/Research/2022-WorkForce-Study/ISC2-Cybersecurity-Workforce-Study.ashx.

Mennecozzi, G. M., Hageman, K., Panum, T.K., Türkmen, A. Mahmoud, R.-V. and Pedersen, J.M. "Bridging the Gap: Adapting a Security Education Platform to a New Audience," *2021 IEEE Global Engineering Education Conference (EDUCON)*, Vienna, Austria, 2021, pp. 153-159, doi: 10.1109/EDUCON46332.2021.9453985.

Panum, Thomas & Hageman, Kaspar & Pedersen, Jens & Hansen, Rene. (2019). Haaukins: A Highly Accessible and Automated Virtualization Platform for Security Education. 236-238. 10.1109/ICALT.2019.00073.

Creation and assessment of learning goals that support competence development

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Abstract

The inclusion of hands-on activities and the use of project-based approaches in several courses in an Engineering program don't necessarily assure the development of the skills that are outlined in the graduate profile. In addition to contributing to student engagement, such activities should have clear learning goals, which uphold the development of the program general skills. Such goals must not only clearly state what students should be able to do after the course, but they also should serve as basis for the design of instruments to assess learning levels and provide each student with feedback, regarding each goal.

Following a backward design approach, this workshop will address the analysis and formulation of learning goals according to these premisses, in a way that supports the design of active learning related activities and the assessment process in Engineering programs.

Keywords: Learning Goals; Assessment in Active Learning; Competence Development.

1 Introduction

For a long time, the process of creating courses in Engineering programs was guided by the content to be taught, rather than the learning objectives. As a result, it has always been common - and in many cases still is - for undergraduate students to complain about not being able to realize the link between what they studied and the skills required to perform the profession they chose.

Traditional Calculus courses provide a classic example of sequential instruction, covering extensive chapters from one or more textbooks in a typical mathematical approach. Often, students are promised that the theory studied will be applied to Engineering problems in the future (Faulkner & Herman, 2017). However, when these real-world applications arise, students may struggle to connect the content they previously learned to the new context. As a result, they may be left with the impression that the depth they experienced in the Calculus courses was not necessary for comprehending the new situation.

In order to deal with the issue of the disparity between university education and the requirements of students' professional lives, "in recent years, there has been a fundamental shift in engineering education from an emphasis on covering content to a student-centric focus on ensuring the attainment of learning outcomes" (Qadir et al., 2020). In this sense, it has been proposed that students be given the chance to engage in genuine problem-solving and knowledge building within genuine professional settings. Project-based learning (PjBL) offers an appealing avenue to accomplish this objective (Guo et al., 2020).

Nevertheless, prior to evaluating the most suitable educational approach, it is necessary to have a clear understanding of the skills that are intended to be developed in students. Merely selecting a particular methodology does not ensure the automatic attainment of learning outcomes. In the case of active learning methodologies, one should avoid what Wiggins and McTighe (2005) identified as one of the two sins of typical instructional design in schools: activity-focused teaching. The authors describe the activity-oriented design error as “engaging experiences that lead only accidentally, if it all, to insight or achievement. The activities, though fun and interesting, do not lead anywhere intellectually”.

We believe that it is more effective for students to learn if each topic is seen as a means to an end, rather than being important in itself. Based on this principle, we propose that courses be created using the 'Backward Design' framework suggested by Wiggins and McTighe (2005). This approach involves starting with clearly defined learning objectives, then designing assessments and instructional strategies that align with those objectives, and finally selecting content that supports the desired outcomes. This systematic approach to course design has been shown to be effective in improving student learning outcomes (Yurtseven & Altun, 2017; Reynolds & Kearns, 2016) and is widely used in educational settings.

In this session, attendees will have the opportunity to both analyze a sample instructional unit design, as well as propose learning goals to a foundational course typically found in Engineering programs.

2 Activities

In the first part, there will be a brief lecture about the theoretical foundation of backward design. Following that, attendees will divide in small groups (4 to 5 people) and will be asked to read an excerpt that describes an instructional unit.

After reading and discussing, one or two groups will be selected to present a brief analysis of the text under the active learning perspective.

Once presentations and discussions are finished, each group will receive the syllabus of a foundational Engineering course and then will be asked to:

- identify 1 or 2 learning goals
- specify evidence of learning regarding such goals
- show an example of activity involving active learning methods that supports the development of abilities related to the proposed goals

3 Expected results

We expect attendees to leave the session not only with a clear understanding that it is not good practice to design courses based solely on the syllabus, but also with the ability to propose and argue for the design of active learning courses aided by the backward design approach.

4 References

Faulkner, B., & Herman, G. (2017). Where does the calculus go? A follow up investigation of how calculus ideas are used in core engineering coursework. 2017 IEEE Frontiers in Education Conference (FIE), Indianapolis, IN, USA, 2017, pp. 1-4.

Guo, P., Saab, N., Post, L. S. & Admiraal, W. (2020). A review of project-based learning in higher education: Student outcomes and measures. International journal of educational research, 102, 101586.

Qadir, J., Taha, A. E. M., Yau, K. L. A, Ponciano, J., Hussain, S., Al-Fuqaha, A., & Imran, M. A. (2020). Leveraging the force of formative assessment & feedback for effective engineering education. ASEE Virtual Annual Conference Content Access, Virtual On-line (2020, june). 10.18260/1-2--34923.

Reynolds, H. L., & Kearns, K. D. (2016). A planning tool for incorporating backward design, active learning, and authentic assessment in the college classroom. College Teaching, 65-1, 17-27.

Wiggins, G., & McTighe, J. (2005). Understanding by design. Virginia: Association for Supervision and Curriculum Development, 2nd edition.

Yurtseven, N., & Altun, S. (2017). Understanding by design (UbD) in EFL teaching: teacher’s professional development and students’ achievement. Educational Sciences: Theory and Practice, 17-2, 437-461.

Hands-On Workshop on Building Assessments with PrairieLearn

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Abstract

PrairieLearn is a powerful online learning platform that enables educators to create parameterized assessments that can be automatically randomized for students. This feature allows instructors to create multiple variations of the same question, each with different values, to encourage students to solve problems rather than memorize answers. In this hands-on workshop, participants will learn how to create parameterized questions and assessments using PrairieLearn. They will be introduced to the platform's interface and will be guided through the steps required to build assessments, configure settings, and analyse student data. The workshop will begin with an overview of the platform's features and benefits, including its ability to generate randomized questions with varying degrees of complexity. Next, participants will explore the platform's question editor, which allows them to create parameterized questions using HTML templates, JSON, and Python. Participants will then move on to creating assessments and configuring settings such as time limits and grading. Finally, they will learn how to download and analyse student data from PrairieLearn to evaluate student performance and identify areas for improvement. By the end of the workshop, participants will be equipped with the skills and knowledge necessary to incorporate this innovative platform into their teaching practice.

Keywords: PrairieLearn, Learning Management Systems, Technology-Enabled Learning.

1 Introduction

PrairieLearn (https://us.prairielearn.com/) is a LMS (Learning Management Systems) tool that uses parametrized questions, that is, questions whose numbers are randomized. In domains such as mathematics and physics, this means that each student can get a personalized version of each question. PrairieLearn is an innovative experience for engineering education, as it can provide a powerful environment fostering student engagement and assessment at a scale.

However, the tool itself has a difficult learning curve, making inexperienced users struggle to learn the correct procedures. In this workshop, participants will be guided through the design a short assessment consisted of a few randomized questions. At the end of the workshop, participants will be able to design activities using PrairieLearn.

This workshop requires participants to have access to a computer or laptop with Internet access. Participation with a mobile device is not possible because the activities will require typing and handling source code. The Internet access can be provided by the conference venue.

2 Activities

The activities planned for the workshop use scaffolding to lead participants into building a small assessment using PrairieLearn and evaluating the results.

The activities require:

- A laptop or desktop computer (a mobile device is not adequate as we will require typing and a keyboard will be extremely useful),

- Internet access (as provided by the conference organization).

Activity name	Objective	Description	Duration (Total: 90 min)
Introduction	Setup laptops and align expectations.	While we setup Internet, laptop access, and platform login to all participants, we briefly discuss the possibilities of PrairieLearn by showing examples of previous courses.	10 min
Create a question	Create a simple multiple-choice question	Briefly go through the steps to create a simple multiple-choice question in the math domain and test it.	10 min
Parametrize a question	Create a parametrized question with a number input	Use Python to make a simple parametrized question in the math domain.	20 min
Setup assessment	Create an assessment and setup grading	Group questions in assessments so they can be shown to students. Test assessments.	20 min
Download student data	Download student data from PrairieLearn and load it into a spreadsheet	Download grades given to students so that they can be incorporated into other, existing learning procedures.	20 min
Final remarks	Indicate further references and collect feedback	Indicate references for further studies and collect anonymous feedback from participants.	10 min

3 Expected results

At the end of this workshop, participants will be able to:

- Create questions in PrairieLearn
- Use Python to parametrize questions in PrairieLearn
- Group questions into assessments that can be used by students
- Evaluate the results of assessments and import data into spreadsheets

4 References

PrairieLearn. (2023). PrairieLearn. Retrieved from https://us.prairielearn.com/

PrairieLearn Documentation. (2023). PrairieLearn Read The Docs. Retrieved from https://prairielearn.readthedocs.io/en/latest/

Morphew J., Silva M., Herman G., West M. (2019), “Frequent mastery testing with second-chance exams leads to enhanced student learning in undergraduate STEM”, Applied Cognitive Psycology, https://doi.org/10.1002/acp.3605, 2019.

Silva M., Hieronymi P., West M., Nytko N., Deshpande A., Chuang J., Hilgenfeldt S., “Innovating and modernizing a Linear Algebra class through teaching computational skills”, Proceedings of the 2022 American Society for Engineering Education Conference (ASEE 2022), 2022.

Reflecting on the delicate task of assessing learning in competency-based training in Engineering Education

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Abstract

This workshop consists of an activity that aims to help engineering professors to understand the difference between assessment (of / for / as) learning and the learning assessment process in competency-based training in Engineering Education, proposing and sharing assessment instruments that can assist in the process.

Keywords: Learning Assessment; Assessment Instruments; Competences; Engineering Education.

1 Introduction

Regarding learning assessment processes, the new National Curriculum Guidelines (DCNs) for Engineering programs in Brazil recommend that different instruments and assessment techniques be used, which allow for a formative and continuous assessment process, considering the skills and competences provided in the profile of the graduate of the program (BRASIL, 2019). The DCNs also emphasize the importance of the active participation of students in the assessment of their own learning, through processes that allow reflection on the learning process itself, the establishment of learning goals and objectives and the development of strategies for its improvement. In addition, the new DCNs recommend that the assessment processes be integrated into teaching, research and extension activities, aiming at the development of a more integrated and contextualized training.

Thus, if these students are exposed to teaching and learning processes, in which the intended learning outcomes, the methodology for developing classes and the assessment instruments are based on a constructivist epistemological conception, the chances of forming competent professionals and aligned with their time increase considerably. Studies indicate that active learning methods and strategies, focused on the student's intellectual actions, in coexistence with their study colleagues, based on the professor's guidelines, are an alternative to be considered in the planning of programs, courses, and classes. Such methods and strategies, when based on doing and understanding, can promote the necessary awareness, essential for learning. In this way, the teaching and learning processes are joined by assessment, which integrates and complements them, providing a diagnosis that allows rethinking and reformulating methods, procedures and learning strategies and methods (Elmôr-Filho et al., 2019; Villas -Boas et al., 2020).

Considering the assessment as a formative process, the professor will map and understand how the student's learning is happening: what are the difficulties, what are the obstacles, what are the advances, what aspects need to be improved, also considering the emotions that permeate this context: anxieties, fears, apprehensions. Thus conceived, the assessment process provides data and information for the professor to program pedagogical interventions, tips and guidelines, problems and challenges so that students establish relationships and develop valuable skills and behaviors. In this way, the assessment is not just a specific moment, but integrates the pedagogical process in a continuous way, constituting a continuous process of diagnosing learning difficulties and obstacles, as a source of reinvention of the pedagogical practice (Lima, Sauer, & Soares, 2007).

According to Cid (2017), assessment, seen as a vehicle for improving learning, brings with it a commitment to creating effective conditions for everyone to learn, promoting a culture of success, supported by the assumption that everyone can learn. This perspective configures procedures for improving teaching and learning processes, recreating the curriculum and implies increasing evaluative contexts that oppose a technical, traditional rationality, and that bet on evaluation as a reflective practice of action, preventing segregation and valuing learning. When assessment is considered as a way of adapting pedagogical strategies and methods focused on students' specificities, it creates the necessary conditions to become a vehicle for educational inclusion.

Assessment is a complex concept in itself and includes a great deal of polysemy. By evaluation we can have different conceptions and what really matters is that each professor is able to identify what his/her conception is based on his/her practice - *tell me how you assess and I'll tell you who you are* (Guerra, 2003). The purposes of assessment go beyond learning assessment - a certifying and summative assessment - especially when we are talking about a competency-based curriculum. Therefore, it is important to consider two other assessment functions (Chappuis, & Stiggins, 2020; Earl, 2012; Hadji, 1994), namely: (i) assessment for learning: a formative assessment, centered on feedback dynamics throughout the process, allowing the student is able to regulate his learning ("Where, how and when can I improve my performance?"); and (ii) assessment as learning – in which the student participates in the assessment process, based, for example, on peer assessment models.

In this sense, assessing skills presupposes integrating the different functions inherent to assessment (of / for / as), diversifying the instruments to be used, with the objective of evaluating different levels of competences.

2 Activities

The activities in this workshop are:

(i) Getting to know the participants' conceptions of learning assessment. In teams, participants will create a mind map or concept map with "Learning Assessment" as the main concept. The map will be posted in the team area followed by a brief presentation of the maps by the teams, followed by a discussion in the large group.

(ii) Using the Write-Share/Write-Pair-Share strategy, the participants will discuss about the difference between assessment (of / for / as) learning.

(iii) In teams, a discussion about the difficulties and the richness of assessing in active learning environments and consequently, about the learning assessment process in competency-based training in Engineering Education.

(iv) A brief exposition with suggestions of assessment instruments that can be used in active learning environments with a focus on developing skills will be held.

(v) In teams, a discussion to raise other assessment instruments that have not been presented in the previous step and are used by team members in their learning environments. Team members will record these assessment instruments on sticky notes that will be posted in the team area.

(vi) As a closing stage of the workshop, a discussion in the large group on what new the workshop brought to the participants in terms of learning assessment process in competency-based training in Engineering Education.

3 Material needed for the workshop

Kraft paper, Scotch tape, markers, regular pens, pencils and post-its.

4 Expected results

By the end of this workshop, we expect that the participants have appropriated the concepts of assessment (of / for / as) learning, have discussed the importance of appropriate assessment instruments for active learning environments and, in particular, have discussed about possible assessment instruments that enhance the learning assessment in competency-based training in Engineering Education.

5 References

BRASIL (2019). Ministério da Educação. Diretrizes Curriculares Nacionais para os Cursos de Engenharia. Resolução CNE/CES nº 2. http://www.in.gov.br/web/dou/-/resolu%C3%87%C3%83o-n%C2%BA-2-de-24-de-abril-de-2019-85344528

Chappuis, J., & Stiggins, R., 2020. Classroom assessment for student learning: Doing it right - using it well (3rd ed.) Pearson Education.

Cid, M. (2017) Avaliar para incluir e melhorar as aprendizagens: práticas, obstáculos e possibilidades. Universidade de Évora. https://dspace.uevora.pt/rdpc/bitstream/10174/22848/1/AVALIAR%20PARA%20INCLUIR%20E%20MELHORAR%20AS%20APRENDIZAGENS.%20PR%C3%81TICAS%2C%20OBST%C3%81CULOS%20E%20POSSIBILIDADES.pdf

Earl, L. M. (2012). Assessment as learning: Using classroom assessment to maximize student learning. Corwin Press.

Guerra, M. S. (2003) Uma seta no alvo. A avaliação como aprendizagem. ASA.

Hadji, C. (1994) A Avaliação, Regras do Jogo. Das Intenções aos Instrumentos. Porto Editora.

Lima, I. G.; Sauer, L. Z.; Soares, E. M. S. (2007). O processo de avaliação integrando o processo de ensino aprendizagem por competências na educação em engenharia. In XXXV Congresso Brasileiro de Educação em Engenharia, COBENGE 2007, Curitiba, Paraná, Brasil.

Villas-Boas, V., Viana, D. M., Mesquita, D., Lira, G. V. B. A., Lima, I. G., Sauer, L. Z., Tavares, L., Soares, L. P., Fontenelle, M. A. M. M., Freitas, M. C. D., Martelli, M. C., Neves, R. M., Lima, R. M., Nascimento, S. C. C. (2021). Educando o engenheiro do século XXI: Aprendizagem Ativa para formação por competências no contexto das novas DCNs. In A. M. Tonini & T. R. D. S. Pereira (Eds.), *Os desafios para formar hoje os engenheiros do Amanhã: Aprendizagem Ativa, Jogos e Gamificação, Novas DCNs e CDIO, Ensino remoto.* (pp. 9-143). Abenge. http://www.abenge.org.br/cobenge/2020/arquivos/EbookDiagramadoSD2020.pdf

Workshop Introduction to Emotional Education in Engineering Education: a hands-on experience

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Abstract

Emotional difficulties have been reported by students in many higher education contexts. In Brazil, according to the National Forum of Deans of Student Affairs, 80% of the students have some emotional difficulty related to money scarcity, high academic workload, inability to organize study routine, and difficulty adapting to new situations. It can be said that, in the Engineering student's context, this situation is the same. Engineering students are always under pressure because of good academic results and many academic and personal duties, without appropriate tools to deal with the emotional roller-coaster called academic life. Emotional education is aligned with many actual imperatives but it is still out of the curriculum and, sometimes, misunderstood and seen as an unimportant issue to students and professors. In this context, this workshop proposal is a possible strategy to introduce professors in emotional education in Engineering education. This workshop will last 2 hours when the participants will go on a journey of self-awareness, emotional alphabetization, group dynamics, and a self-assessment questionnaire designed to permit the participants to evaluate their various competencies of emotional intelligence. The workshop will have the following activities scheduled: 1) Introduction 2) Group dynamics to group integration and sharing of their concept of emotions 3) Participants will create their Self-awareness Canvas 4) Presentation of concepts and key authors about Emotional Intelligence 5) Presentation of Emotional Intelligence Tool Kit 6) Presentation of Emotional Intelligence Questionnaire 7) Participants quality assessment of the workshop and conclusions.

Keywords: Active Learning; Engineering Education; Conference Information; Project Approaches.

1 Introduction

The human dimension of engineering education has been emphasized worldwide. Some movements such as the Bologna Convention proposing a learning-centered education around Europe and even the Brazilian Curricular Guidelines to Engineering Programs are some examples of an attempt to adapt the learning process to a fast-changing labor market which demands a holistic approach in the context of engineering education (Vipin, Panicker & Sridharan, 2012).

In this circumstance, the discussion addresses a new paradigm of teaching-learning that has placed the student at the center of education. In this context, it is important to affirm that education must encompass the various dimensions of the student, such as the physical, the emotional, the intellectual and the spiritual dimensions of the individual (Vipin, Panicker & Sridharan, 2012). Considering the changing and competitive society, where the demand for future graduates is in constant reformulation, it is critical to help students to recognize and to develop their socio-emotional dimension (Casado, López & Lapuerta, 2016).

This analysis becomes even more challenging considering the prevalence of common mental disorders (CMD) among higher education students (Lopes et al., 2022). CMD is a group of signs of somatic and emotional symptoms that include: insomnia, fatigue, physical malaise, irritability, sadness, nervousness, anxiety, stress, forgetfulness, difficulty concentrating, and feeling worthless. Considering national and international literature, it is possible to indicate that the academic routine makes students vulnerable to the development of some mental disorders such as depression, anxiety, and stress (Lopes et al, 2022; FONAPRACE, 2019).
Considering all this context, some initiatives have been executed to promote emotional education to students. It is assumed that socio-emotional skills must be included in the engineering curriculum (Chisholm, 2010).

Despite that, in Brazil, emotional education is still out of the curriculum and, sometimes, misunderstood and seen as an unimportant issue by students and professors.
This workshop aims to give the participants an introduction to Emotional Education based on an initiative that was held at The Federal University of Itajubá – Itabira campus as a possible strategy to include emotional education in this Engineering institution. It will be a 2-hour workshop that can be offered to the university community to let participants go on a journey of self-awareness, emotional alphabetization, group dynamics, and a self-assessment questionnaire designed to permit the participants to evaluate their various competencies of emotional intelligence.

2 Activities

1) Introduction: to introduce the workshop, the instructor will present herself and explain the motives for studying Emotional Education and preparing this workshop. As a professor at the Federal University of Itajubá – Itabira campus, since 2010, it has noticed the increased incidence of students reporting common mental disorders (CMD). According to Lopes et al (2022), there is a prevalence of CMD among higher education students (Lopes et al., 2022). CMD is a group of signs of somatic and emotional symptoms that include: insomnia, fatigue, physical malaise, irritability, sadness, nervousness, anxiety, stress, forgetfulness, difficulty concentrating, and feeling worthless. Considering national and international literature, it is possible to indicate that the academic routine makes students vulnerable to the development of some mental disorders such as depression, anxiety, and stress (Lopes et al., 2022; FONAPRACE, 2019).
2) Group dynamics to group integration and sharing of their concept of emotions - Evoking emotions: participants will be shown several toys, and each participant will choose a toy and say what emotion that object evoked (Figure 3). This will be an opportunity for participants to mention emotions, feelings, and behaviors related to the mentioned emotions and collectively share how they deal with emotions. The instructor will consider the participants' reports and lead the discussion using the concept of Caruso & Salovey (2004) that emotion is not just important but necessary to make good decisions, take action to solve problems, cope with change, and succeed.

Figure 1: Material used in the Dynamic Evoking Emotions

3) Participants will create their Self-awareness Canvas: a self-awareness canvas will be proposed to participants. According to Eurich (2017), one must follow seven insights to grow self-awareness or the capacity to know oneself. As advocated by Eurich (2017), self-awareness is a meta-competency that must be acquired before developing other soft skills. In this sense, Eurich (2017) defends that there are seven forms of insight, all of which must be developed to become wholly self-aware. Participants were invited to use an A3 canvas (Figure 3) with the 7 seven insights: values, passions, aspirations, fit, patterns, reaction, and impact. After participants filled out their canvas, it was considered that emotional intelligence relies on self-awareness as someone can only reach their full potential when this person knows her/himself enough to make the best decisions given his/her personal goals.

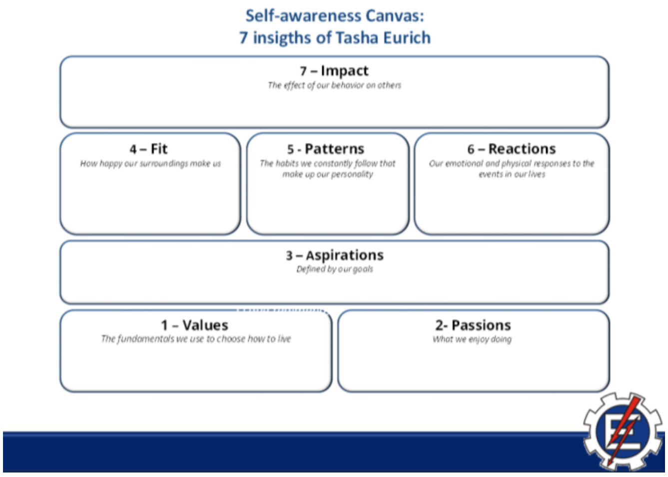
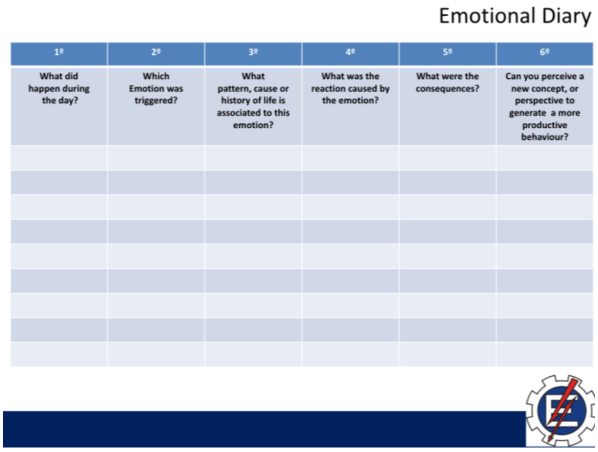


Figure 2: Self-awareness canvas - 7 insights of Tasha Eurich

4) Presentation of concepts and key authors about Emotional Intelligence: some concepts of emotions will be shown to participants, such as Ekman (2011), which consider basic emotions such as joy, sadness, fear, surprise, disgust, contempt, and anger. Goleman´s (1995) definition of emotion was shared as "a feeling and its distinctive thoughts, psychological and biological states, and range of propensities to act" (Goleman, 1995). As it is a practical workshop, the theoretical explanation of the concept will not be explored, but there is special care to cite reputable authors and provide all the references to participants.

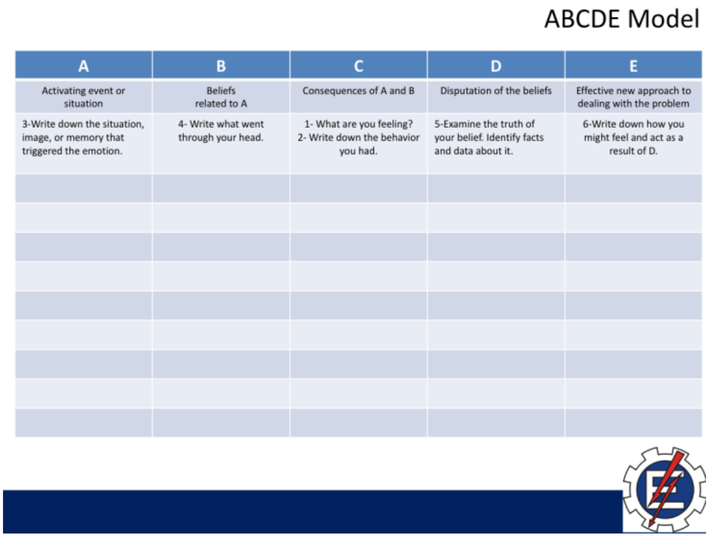
5) Presentation of Emotional Intelligence Tool Kit: as practical exercises of emotional intelligence, two techniques will be presented so that the participants would practice the awareness of their emotions and their reflexes in daily life. The first technique will be the Emotional Diary, based on rational-emotive behavioral therapy by Ellis (1971), as placed in Figure 4. The Emotional Diary leads the participant to a process of self-reflection and awareness of the effects of daily events and the emergence of emotions, thoughts, and behaviors. In this diary, the participant is invited to reflect on how to re-signify events and choose more productive decisions in future situations.


Emotional Diary

1º	2º	3º	4º	5º	6º
What did happen during the day?	Which Emotion was triggered?	What pattern, cause or history of life is associated to this emotion?	What was the reaction caused by the emotion?	What were the consequences?	Can you perceive a new concept, or perspective to generate a more productive behaviour?

Figure 3: Emotional Diary

The second technique that will be presented to participants is the ABCDE model (Figure 6). It is a behavioral therapy model that guides the participant through five stages: 1) Activating event or situation, 2) Beliefs, 3) Consequences, 4) Disputation of the beliefs, and 5) Effective new approach to dealing with the problem. The purpose of this model is to challenge an individual's negative or unhelpful beliefs and replace them with new, helpful ways of thinking. In addition to this model, the concept of cognitive distortion (Beck, 2022) will be presented to help students to deal with unfounded thoughts that disturb productive behavior.


ABCDE Model

A	B	C	D	E
Activating event or situation	Beliefs related to A	Consequences of A and B	Disputation of the beliefs	Effective new approach to dealing with the problem
3-Write down the situation, image, or memory that triggered the emotion.	4- Write what went through your head.	1- What are you feeling? 2- Write down the behavior you had.	5-Examine the truth of your belief. Identify facts and data about it.	6-Write down how you might feel and act as a result of D.

Figure 4: ABCDE Model

6) Presentation of Emotional Intelligence Questionnaire: a self-assessment questionnaire will be proposed to participants as a tool for self-reflection about their emotional intelligence skills. It was designed according to Goleman (2011) that considers the following emotional intelligence skills: self-awareness; managing emotional behaviors; self-motivation; empathy, and social skill. This questionnaire was created and disseminated by NHS England in the Program Leading Across London (2014). After answering this questionnaire, the participants will be invited to assess and score 50 statements related to emotional intelligence skills. After that, they can interpret the totals for each area of emotional intelligence, analyzing their weakness and their strengths. At the end, they will be asked to consider the results and identify one or two actions that could be taken immediately to strengthen their emotional intelligence.

7) Participants´ quality assessment of the workshop and conclusions: In the end of the discussion, an assessment questionnaire will be proposed to the participants to know the results and the improvement opportunities of this workshop. To conclude the experience, the participants will be asked about the possibility of using the workshop as a model of introduction to Emotional Education in their institutions.

3 Expected results

The objective of this workshop is to introduce emotional education to the participants as a reference that can be adapted and used in their institutions. It will be shown some important concepts, authors, and techniques that can be easily applied in the context of engineering education.

4 References

Beck, J. S. (2022) Terapia cognitivo-comportamental: teoria e prática. 3 ed. Porto Alegre: Artmed.

Caruso, D. R., & Salovey, P. (2004). The emotionally intelligent manager: How to develop and use the four key emotional skills of leadership. John Wiley & Sons.

Casado, M. L., López, D., & Lapuerta, V. (2016). Socio-emotional competencies in Engineering Education. International Journal of Engineering Education, 32(4), 1660-1678.

Chisholm, C. The formation of engineers through the development of Emotional Intelligence and Emotional Competence for global practice, Global Journal of Engineering Education, GJEE, 12(1), 2010, pp.6–11.

Ekman, P. (2011). A linguagem das emoções. São Paulo: Lua de Papel, 77-108.

Ellis, A. (1974). Rational-emotive theory: Albert Ellis.

Eurich, T. (2017). Insight: The power of self-awareness in a self-deluded world. Macmillan.

Fórum Nacional de Pró-Reitores de Assuntos Comunitários e Estudantis - FONAPRACE (2019). V Pesquisa Nacional de Perfil Socioeconômico e Cultural dos(as) Graduandos(as) das Instituições Federais de Ensino Superior. http://www.andifes.org.br/wp-content/uploads/2019/05/V-PesquisaNacional-de-Perfil-Socioeconômico-e-Cultural-dos-as-Graduandos-as-das-IFES-2018.pdf

Goleman, D. (2011). Emotional intelligence. Objetiva.

Leading Across London. (2014) Emotional intelligence questionnaire. Outcomes measurement tool: attitudes & feelings - emotional intelligence. London: NHS England. https://www.drugsandalcohol.ie/26776/1/Emotional_intelligence_questionnaire-LAL1.pdf

Lopes, F. M., Lessa, R. T., Carvalho, R. A., Reichert, R. A., Andrade, A. L. M., & De Micheli, D. (2022). Transtornos mentais comuns em estudantes universitários: uma revisão sistemática da literatura. Revista Psicologia em Pesquisa, 16(1), 1-23.

Vipin, B., Panicker, V. V., & Sridharan, R. (2012, July). Transformation process in engineering education: A holistic approach. In 2012 IEEE International Conference on Engineering Education: Innovative Practices and Future Trends (AICERA) (pp. 1-4). IEEE.