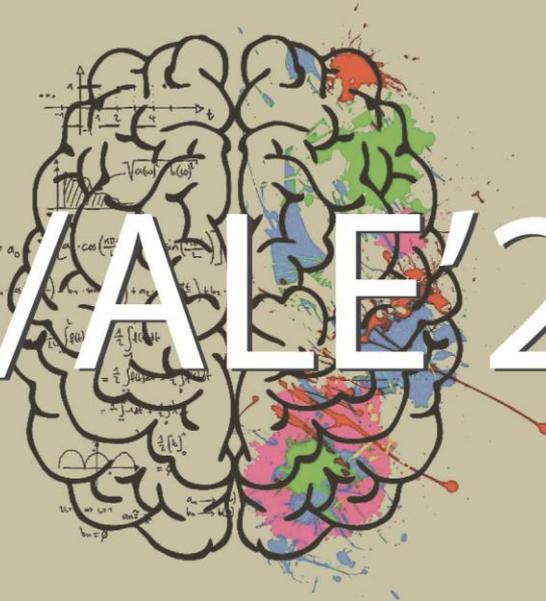


INTERNATIONAL CONFERENCE
ON ACTIVE LEARNING IN ENGINEERING EDUCATION



Planting the seed:
Promoting engineers with global awareness

PAEE/ALE'2022



6 - 8 July 2022. Alicante - Spain



ALE



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This is a digital edition.

WELCOME TO PAEE/ALE'2022

Dear Participants,

Welcome to the International Conference on Active Learning in Engineering Education (PAEE/ALE'2022). This is the seventh collaboration of the International Symposium on Project Approaches in Engineering Education (PAEE) and the Active Learning in Engineering Education Workshop (ALE).

The theme of the conference is "Planting the seed: promoting engineers with global awareness". The world needs engineers that know how to establish a collaborative culture in their workplace and how to deal/communicate/negotiate with people from different countries and cultures. Engineering schools and faculty need to help their students to develop socio-emotional and intercultural skills that will provide the future engineer with the competence needed to work in complex global contexts. Active learning strategies and methods can be great tools for the development of these skills. By defining this theme, we would like to raise awareness to ensure a guarantee of personal dignity, the free flow of persons without any discrimination, and the right to effective equality between women and men.

Renowned keynote speakers from the Engineering Education and Sustainability areas will be present in this PAEE/ALE edition sharing their experience with the participants. Besides, the offer of hands-on sessions will generate learning-by-doing experiences that will allow experimentation and discussion of the proposals presented.

May the International Conference on Active Learning in Engineering Education (PAEE/ALE'2022) be a fruitful forum where participants, in their permanent need for continuing education, will have the opportunity to discuss research and current practice under this challenging theme of promoting engineers with global awareness.

We would like to express our sincere gratitude to the participants that made this event possible and for all the support that we had during this last year from different people and organizations.

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

Miguel Romá & Valquíria Villas-Boas

(Chairs of the PAEE/ALE'2022)

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PAEE/ALE'2022 Invited Speakers

PAEE/ALE'2022 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:

- Antonio Turiel (Nacional Research Council, Spain)
- Shannon Chance (TU Dublin, UK)
- Jordi Segalàs (Univesitat politècnica de Catalunya, Spain)

Antonio Turiel

National research council (CSIC), Spain

Title of the keynote – Science curricula in the time of resource scarcity

Short bio



Antonio Turiel was born in León, Spain, in 1970. He is a Senior Scientist at the Institute for Marine Sciences of Barcelona (CSIC, Spain) where he carries out research on physical oceanography using the principle of fluid mechanics and thermodynamics. He has been also engaged on a intense scientific communication activity regarding the depletion of conventional fossil fuel resources and the anthropogenic causes of climate change as well as the failure of the capitalist mode of production. He is the editor and main author of the scientific blog *The Oil Crash*, which became a benchmark on these topics.

ShannonChance

TU Dublin, UK

Title of the keynote – Engineering knowledge, skills and values: keys to fostering globally responsible changemakers

Short bio



Shannon Chance is a fully qualified Architect, licensed to practice in the Commonwealth of Virginia and a Council Record Holder in the National Council of Architectural Registration Boards since 2005, meaning that she is eligible for reciprocity/licensure in any state within the USA. She has also been a LEED Accredited Professional (LEED-AP) under the United States Green Building Council's Leadership in Energy and Environmental Design program since 2009. Shannon's PhD thesis, in the area of Higher Education Policy, Planning and Leadership, looked at how universities have been using green building rating systems to develop their built assets; she assessed to what degree their efforts constituted actual "leadership" in environmental sustainability. She presented findings at NASA Langley. Her thesis earned the Outstanding Dissertation Award from the International Society for Educational Planning and she graduated with the sole 2010 Dean's Award for PhD students in her School. Aiming to work at the cutting edge of architecture and building environment, Shannon recently completed a Postgraduate Certificate in Building Information Modeling (BIM) in Ireland. Shannon has accepted global leadership roles, serving as Associate Editor for *IEEE Transactions on Education*, an Editorial Board member of the *European Journal of Engineering Education*, and 2020-2022 Chair of the global Research on Engineering Education Network which organizes a bi-annual symposium (upcoming in Australia and India) and publishes special focus journal issues. Shannon is lead guest editor on a new special focus issue on ethics in engineering education and practice to be published spring 2021. She is also a mentor for TU Dublin researchers as well as the *Journal of Engineering Education*.

Jordi Segalàs

Universitat Politècnica de Catalunya (UPC), Spain

Title of the keynote – The ‘whys’, ‘whats’, ‘hows’ and ‘whos’ of Sustainability in Engineering Education

Short bio



Jordi Segalàs works as associate professor at the Research Institute of Sustainability Science and Technology in the Universitat Politècnica de Catalunya UPC-Barcelona Tech. He is the head of the Research Group on Sustainability Education and Technology in Higher Education. He has been the Director of the Catalan Network of Education for Sustainability. He obtained his PhD in Sustainability Education in Engineering from Barcelona Tech University. He has been working in curriculum greening policies and actions plans at the Barcelona Tech University since 2000. He is also working in TEMPUS (trans-European cooperation scheme for higher education) projects related to sustainable development in higher education. He has published more than 60 articles on higher education and sustainability. He is the chair of the Sustainability working group of SEFI. He has been working in curriculum greening policies and action plans since 2000.

PAEE/ALE'2022 Programme

	06/07/2022	07/07/2022	08/07/2022
8:00	Registration desk		
8:30-9:30	Opening ceremony Ice-breaking activity	Registration desk	Registration desk
9:30-11:00	Hands-On sessions HO.1 / HO.2	KEY-NOTE session Shannon Chance <i>"Engineering knowledge, skills, and values: keys to fostering globally responsible changemakers"</i>	Papers session 3 <i>Gamification</i> Hands-On session HO.5
11:00-11:30	Coffee break	Coffee break	Coffee break
11:30-13:00	Papers session 1 <i>Students engagement</i>	Hands-On sessions HO.3 / HO.4	Papers session 4 <i>Impact on social development</i> <i>Multidisciplinary approaches</i>
13:15-14:30	LUNCH	LUNCH	Closing ceremony LUNCH (not included in the fee)
14:30-16:00	Papers session 2 <i>Research on Engineering Education</i>	KEY-NOTE session Jordi Segalás <i>"The 'whys', 'whats', 'hows' and 'whos' of Sustainability in Engineering Education"</i>	<i>Post-conference</i> <i>Visit labs:</i> <i>Human Robotics (HURO),</i> <i>Big structures (LARGE),</i> <i>Autonomous vehicles (Quixmind)</i>
16:00-16:30	Coffee break	Coffee break	
16:30-18:00	KEY-NOTE session Antonio Turiel <i>"Science curricula in the time of resource scarcity"</i>	Students session ST.1 / ST.2	
18:00-19:30	PAEE/ALE Challenge + Wellcome cocktail	Cultural activity and Conferene Dinner	

PAEE/ALE'2022 Paper Sessions, Hands-On Sessions and Students Sessions

Day 1

Day 1: Wednesday, 6 July 2022	
8:30-9:30	Opening ceremony & Ice-breaking activity (Room A)
9:30-11:00	Hands On Session 1 (Room C) Miguel Romá 20 <i>Do we, as educators, have to be neutral in our classroom?</i>
	Hands On Session 2 (Room E) Montse Farreras, Armengol Jesús, Pau Bofill, Àngels Hernández 29 <i>Game-based Learning vs Gamification: A Hands-On</i>
11:00-11:30	Coffee break (Inner courtyard)
11:30-13:00	Papers Session 1 (Room B) – Student Engagement Session Chair: Anabela Alves Jose Ignacio Pagan, Pablo Ortiz, Isabel Lopez 7 <i>The use of Kahoot! to promote Active Learning in Port Management and Operation subject in Civil Engineering degree</i> Jose Ignacio Pagan, Isabel Lopez, Pablo Ortiz 9 <i>Use of video tutorials for Active Learning and PBL in Coastal Engineering subject</i> Sandra Fernandes, Anabela Alves, Celina P. Leao, Ana Pereira 49 <i>Promoting assessment as learning in PBL: findings from blogs created by first year students</i> Sandra Fernandes, Marta Abelha, Ana Sílvia Albuquerque 50 <i>The student journey in PBL: using individual portfolios to promote self-reflection and assessment as learning</i> Anabela Alves, Sérgio Oliveira, Celina P. Leão, Sandra Fernandes 45 <i>IEM@ProjectNetworking revisited: freshmen students closer to professional practice</i> Javier Ramirez Angulo, Margarita Portilla Pineda, Maria del Carmen González Cortés 61 <i>Conducting a Home Experiment Related to the Colligative Properties of Chemical Solutions</i>
	13:15-14:30
14:30-16:00	Papers Session 2 (Room B) – Research on Engineering Education Session Chair: Shannon Chance Miguel Romá, Josep David Ballester, Francisco Pedro Vives 10 <i>Strengths and dangers of self and peer assessment in engineering learning. Teachers' and students' perspective</i> Dianne Viana, Valquíria Villas-Boas 13 <i>Do Brazilian Engineering Professors Do Engineering Education Research in Active Learning? A Case Study</i> Rosane Aragón, Crediné Menezes, Alberto Castro Junior 48 <i>Learning Assessment in a "Theses Debate"</i> Teresa Hattingh 67 <i>Are your rubrics hitting the mark? An exploration of the use of rubrics for project-based learning in engineering</i> Daniela Pedrosa, Leonel Morgado and José Cravino 72 <i>A strategy to support Engineering Education teaching staff monitoring students' learning process: Metacognitive Challenges</i>
	16:00-16:30
16:30-18:00	KEY-NOTE Session (Room A) Antonio Turiel <i>Science curricula in the time of resource scarcity</i>
18:00-20:00	PAEE/ALE Challenge + Welcome cocktail

Day 2

Day 2: Thursday, 7 July 2022		
9:30-11:00	<p align="center">KEY-NOTE Session (Room A) Shannon Chance <i>Engineering knowledge, skills, and values: keys to fostering globally responsible changemakers</i></p>	
11:00-11:30	<p align="center">Coffee break (Inner courtyard)</p>	
11:30-13:00	<p align="center">Hands On Session 3 (Room D) - laptop required</p> <p>Jens Myrup Pedersen <i>54 Haaukins: Cyber Security Training with Gamification</i></p>	<p align="center">Hands On Session 4 (Room C)</p> <p>Elisandra Martins, Valquiria Villas-Boas <i>31 Engineers working as a team: socio-emotional and intercultural skills for multicultural environments</i></p>
13:15-14:30	<p align="center">LUNCH (Inner courtyard)</p>	
14:30-16:00	<p align="center">KEY-NOTE Session (Room A) Jordi Segalàs <i>The 'whys', 'whats', 'hows' and 'whos' of Sustainability in Engineering Education</i></p>	
16:00-16:30	<p align="center">Coffee break (Inner courtyard)</p>	
16:30-18:00	<p align="center">Students Session – Local/Online (Room B) Session Chair: Jens Myrup Pedersen</p> <p><i>(On-site) Pablo Ortiz, Jose Ignacio Pagan and Isabel Lopez</i> <i>8 Entrepreneurship as a tool to facilitate job placement for civil engineering students</i></p> <p><i>(On-site) Lluís Bernat, Carlos A. Jara, Jose L. Ramon, Jorge Pomares, Gabriel J. Garcia, Andres Ubeda</i> <i>22 Exoforge: Interdisciplinary teaching laboratory for the development of assistive technology projects</i></p> <p><i>(On-site) Isabel B. A. de Souza, Bruno L. Borba, Alexandre S. C. Costa, Simone B. S. Monteiro, Edgar C. Oliveira</i> <i>57 PBL to design a Gamified Financial Management Application for the socially vulnerable</i></p> <p><i>(On-site) Moises A. Croes, Carlos A. Jara, Jose L. Ramón, Jorge Pomares, Gabriel J. García, Andrés Ubeda</i> <i>62 An advanced application for learning robotics using Augmented Reality</i></p> <p>Miriam Chan-Pavón, Jesús Escalante-Euán, Ileana Monsreal-Barrera, Carlos Rubio-Atoche <i>23 Exploration of the use of Project Based Learning (PBL) methodology in two accredited engineering programs at the Universidad Autónoma de Yucatán</i></p> <p>Cláudia Gonçalves, João Neto, Sabrina Oliveira and José Dinis-Carvalho <i>14 Project-based learning applied to improve the performance of a family wine bottling unit</i></p> <p>Matheus Ferreira Palú, Octavio Mattasoglio Neto, Eduardo Nadaletto da Matta <i>28 Multidisciplinary projects for Engineering, Business Administration and Design programs: Construction and mapping of common skills through an analysis instrument</i></p> <p>Matheus Ricardo de Avila Santos, Maria Valéria Araújo, John Burgoyne, Dmitryev Silva, Diego Paes, Rebeka Alves and Ana Beatriz Santana <i>4 Serious Game with emphasis on Global Prosperity: developing the Game Reis Magos from Design Science</i></p>	<p align="center">Students Session – Online Session Chair: Vicente Morell</p> <p>Bruna Andrade Machado, Bárbara Hotta, Gabriel Lino Garcia, Fernando Bernardi Souza, José De Souza Rodrigues <i>25 The use of games in the teaching of Production Engineering: a catalog based on publications in Scopus</i></p> <p>Bárbara Yumi Hotta, Fernando Bernardi Souza, Bruna Andrade Machado, José De Souza Rodrigues <i>26 Evaluation of the effectiveness of the use of games in the teaching of Production Engineering: an experiment with Goldratt Simulator</i></p> <p>Humberto Arruda, Edison R. Silva <i>34 Lecturer Self-Awareness Index: measuring the alignment between lecturer and student perception</i></p> <p>Mariana de Azevedo Mello, Júlia Rocha Thomaz Mattoso Salgado, Marcelle Caldas Vicente, Fernando Augusto Ullmann Töbe, Stephany Rie Yamamoto Gushiken, Anibal Alberto Vilcapoma Ignácio <i>38 Application of Project-Based Learning and Lean tools in a machining area of a welding industry</i></p> <p>Amanda Rocha, Ingrid Alves, Larissa Santos, Laura Sousa, Dianne Viana, Maura Shzu, Simone Lisniowski <i>39 An approach to encourage girls' protagonism in exact sciences and engineering</i></p> <p>Mariane Souza, Rui Lima, Diana Mesquita, Elida Margalho <i>43 Development and Validation of Scenarios for the assessment of Project Management People Competences</i></p> <p>Jose Cristiano Pereira, Flavio Almeida, Ercilia de Stefano <i>68 Proposal of Method for Risk Assessment of Project-Based Learning Failure via AHP and BBN aiming at improving the Quality of Engineering Education – A Case Study</i></p> <p>Nicole Andressa Michel, Luiz Campos <i>71 Circular Economy Implemented in a Cosmetic Company: A Case Study</i></p>
19:00 ->	<p align="center">Cultural Activity – Visit to Santa Bàrbara Castle (bus ride) and Alicante historic centre</p> <p align="center">&</p> <p align="center">Conference dinner</p>	

Day 3

Day 3: Fryday, 8 July 2022	
9:30-11:00	<p>Papers Session 3 (Room B) – Gamification</p> <p>Session Chair: Sandra Fernandes</p> <p>Pau Bofill, Montse Farreras, Jesús Armengol 30 <i>An Escape Room For Learning Computer Programming</i></p> <p>Montse Farreras, Pau Bofill, Jesús Armengol 33 <i>An escape room for an alternative evaluation system</i></p> <p>Andres Ubeda, Gabriel J. Garcia, Vicente Morell, Jose L. Ramon, Maria J. Blanes 21 <i>A gamification approach for continuous engagement in engineering courses</i></p> <p>Jesús Armengol, Pau Bofill, Montserrat Farreras 35 <i>Gaming for learning</i></p>
	<p>Hands On Session 5 (Room C)</p> <p>Jens Myrup Pedersen 53 <i>Problem Based Learning – Making Blended Learning work!</i></p>
11:00-11:30	Coffee break (Inner courtyard)
11:30-13:00	<p>Papers Session 4 (Room B)</p> <p>Session Chair: Rui Sousa</p> <p>Social Development</p> <p>Tatiane Evangelista 59 <i>Seeding future engineers</i></p> <p>Fernando J. Rodriguez-Mesa 66 <i>The Torca Experimen: A model of transdisciplinary project-work</i></p> <p>Multidisciplinary Approaches</p> <p>Victor Paiva, Caio Santos 11 <i>Project based learning approach in the heat transfer course for undergraduate students</i></p> <p>Luciano Soares, Fabio Orfali 37 <i>Pair Teaching in Computer Graphics</i></p> <p>Celina P. Leão, M. Florentina Abreu, Anabela Alves and Sandra Fernandes 55 <i>PBL tutoring dynamics in first-year of Industrial Engineering and Management Program</i></p>
13:00-13:30	Closing Ceremony (Room A)
13:30-14:30	LUNCH (not included in the fees)
15:00-17:00	<p>Post-Conference Visit</p> <p>Human Robotics (HURO): <i>Robotic engineering</i></p> <p>Big structures (LARGE): <i>Civil engineering</i></p> <p>Autonomous industrial vehicles (Quixmind)</p>

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PAEE/ALE'2022 Submissions

The PAEE/ALE'2022, International Conference on Active Learning in Engineering Education, joins the International Symposium on Project Approaches in Engineering Education – PAEE, which is being organized by PAEE association, the Department of Production and Systems, of the School of Engineering, University of Minho, since 2009, and the ALE workshop, which is being organized by the ALE Network, since 2000. PAEE/ALE'2022 aims to join teachers, researchers on Engineering Education, deans of Engineering Schools and professionals concerned with Engineering Education, to enhance engineering education through Active Learning and Project Approaches through workshops and discussion of current practice and research. PAEE/ALE'2022 event is hybrid, with both full online and local on site sessions.

The event has three type of submissions in English:

- **Hands-on and Workshop submissions**, aiming to encourage discussion of current practice and research on project approaches.
- **Full Papers** for paper sessions, including standard research submissions, and papers of innovative experiences describing implementation issues.
- **Abstract submissions**, which is a short submission that may be included in paper session presentations or poster sessions presentations.

All full paper submissions were double reviewed by the PAEE/ALE'2022 scientific committee, and in some cases had a third review. PAEE/ALE use a single blind review procedure. After notification of acceptance authors were invited to submit a final paper of 6 to 8 pages long in Microsoft Word format, using the available template. Accepted contributions were invited to make a presentation at the symposium.

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- Expect original submissions from the authors and discourage misconduct.
- Expect that authors are responsible for language quality.
- Expect that the authors adequately reference the sources of their work.
- Ensure confidentiality of submissions and reviews.
- Reviewers do a fair and detailed review of paper(s) assigned to them.

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PAEE/ALE'2022 Full Papers Submissions

Submissions accepted for the PAEE/ALE'2022 papers sessions in English.

Serious Game with emphasis on Global Prosperity: developing the Game Reis Magos from Design Science

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Abstract

Serious Games increasingly receive the support and interest from teachers as another active teaching methodology that, built to achieve educational goals, also manages to motivate and attract the attention of students. The objective of the research is to describe the development of a serious game used to assist in the teaching-learning process of global prosperity. To this end, qualitative research was performed, adopting the Design Science model. As for the results, it was identified that constant testing added value to the construction of the game. Another contribution of the study is the emphasis on the concern that developers or educators must have regarding some elements in games, such as the rules and mechanics. The research brought contributions to the educational process, as well as business practice, with the combination of teaching cases and educational games.

Keywords: Case Method. Global Prosperity. Design Science.

1 Introduction

The social and technological context and new contemporary social habits and practices, in addition to the generation of digital natives (Prensky, 2003) who have an innate ability to learn how to interact online (McGonigal, 2011) trigger the growing emergence of new approaches and educational possibilities, allowing the expansion of pedagogical actions in the classroom (Figueiredo, et al., 2015).

From this perspective, active learning methodologies, such as case studies and serious games, have several advantages: allowing for the establishment of links between the teaching environment and the real world; leading students to the variability of solutions; favouring the establishment of relationships between variables; contributing to the analysis of a problem from different points of view; requiring students to publicly express their ideas and subject them to criticism; adjusting to different levels of teaching complexity, and they can also be used both in face-to-face and distance learning (Alves et al., 2015; Bacich & Moran, 2018).

As an active learning methodology, Teaching Cases are commonly used as a complement to other teaching methods, usually based on the deductive method of teaching-learning, thus, they are based on theories, models, or concepts (Roesch, 2007).

For Alves et al. (2015), Gamification is an active teaching methodology that arises, in this sense, with the principle of appropriation of elements used in games for contexts of products and services not focused on games, but to promote engagement and learning. Unlike games, the goal of gamification is not just having fun, hence serious games.

The gamification process analyzed here had the pedagogical purpose of teaching and making students aware of the concept of Global Prosperity. This concept has emerged in recent decades questioning the centrality of economic growth as a measure of success and well-being of a community, proposing a multifaceted analysis that considers alternative and contextualized values to judge the quality of life of a society.

Since its establishment, the concept of Sustainable Development, and initiatives derived from it, have become the target of criticism, either for the false symmetry between the three factors propagated (Flint, 2010; Paes,

2017), for the impossibility of reconciling an ecologically viable economy with the objectives of a capitalist system (Vizeu, et al., 2012), or by the contradictions of equalizing “growth” with the obvious limitations of resources (Misoczky & Böhm 2012).

In this context, the concept of Global Prosperity emerges as a critical alternative to the unifying perspective of Sustainable Development, focused on growth. Thus, the concept is particularly averse to the vision of prosperity in a community defined by the notion of economic wealth (Sender et al, 2020).

In this way, the research aims to describe the development of a serious game to assist in teaching-learning Global Prosperity from tests with Design Science. To achieve this objective, the following specific objectives were defined: presenting the process of game building; - presenting the adjustments in the game structure; - describing the structural elements of the game; - describing the game.

1.1 Theoretical elements

To understand the theoretical elements that would be part of the game, the researchers focused on comprehending the design that a game should have, and for that, they were based on the Theory of Flow, and also, to achieve educational goals, the Theory of Global Prosperity was deepened, bringing to the game a reflexive character about the complex reality surrounding the player.

Kirriemuir and McFarlene (2004) comment that several researchers and video game developers based their investigations on the theory of flow (figure 1), that shows that the shape or state of the flow depends on a combination of challenges and skills.

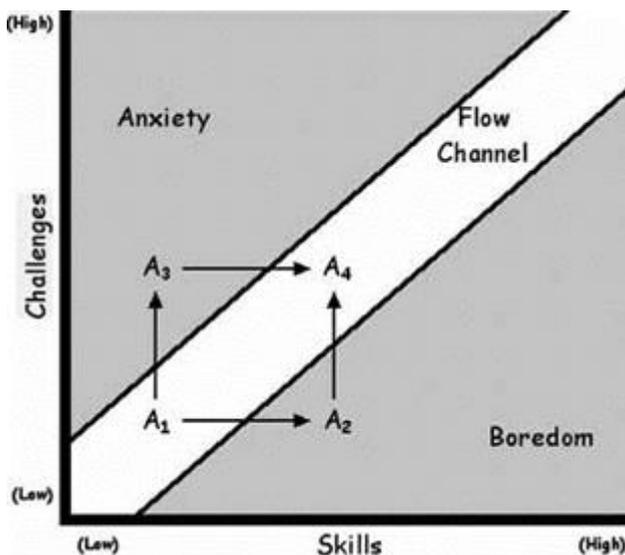


Figure 1. Theory of flow source: Csikszentmihalyi, 1990.

For a person to reach a state of flow or challenge, they must report to the level of their own difficulties. For example, in a situation (A1), the person is still learning to play with only a few skills at that time, or with reduced challenge levels, so the degree of difficulty is suited to their skill (Csikszentmihalyi, 1990).

At this point, we are in a flow situation, which is likely to be short-lived, as the player will improve their dexterity by repeating and adapting to the flow of the game. If no level changes occur in the challenge (A2), the player will start to feel bored and presumably give up on the task. If the challenges are too far above the obstacles, it will cause anxiety (A3), which can also lead to abandoning the game.

Lopes and Oliveira (2013) state that for a flow situation to occur, a continuous balance is needed between the challenges presented and the current capabilities of the player ($A1 > A4$).

From a game-components perspective, Busarello (2016) highlights that gamification values five structural elements: 1) learning; 2) game mechanics; 3) in-game thinking; 4) motivation and engagement; 5) narrative.

Vianna et al. (2013) and Zichermann and Cunningham (2011) point out that, to keep the student motivated in the game building process, it is necessary to appropriate its most efficient elements - mechanics, dynamic and aesthetic. The first comprises the elements of the functioning of the game, that guide the player in their actions; while the second are the moments of interaction between the player and these mechanics; and, finally, the aesthetic refers to the emotions of the players in the moments of interaction with the game, also reflecting the previous relationships with mechanics and dynamics.

Hanus and Fox (2015) emphasize that one must be careful when defining rewards throughout the game, because certain extrinsic rewards can destroy intrinsic motivations, affecting the motivational aspect of the individual.

In this way, for the proposed game, a theory that contemplated a model extrapolating the 'economicist' metrics was designed. Sustainability sees growth, in an economic sense, as necessary, especially with regard to solving poverty and misery, emphasizing metrics such as GDP and family income.

In this sense, the concept of Global Prosperity promotes a multifaceted vision capable of seeing beyond the economic dimension, incorporating values, quality of life, and well-being in its analysis, given a specific context (Moore, 2015). For a real Prosperity to be sustainable, it must combine the development of the ability to live well on a planet with finite resources, with the quality of life and relationships, the resilience of communities, and a sense of collective and individual meaning (Jackson, 2017).

Thus, Global Prosperity envisages rethinking global society and its priorities, reframing much of what is thought about life in the global south. Although historically classified as "developing" or "underdeveloped", the rupture of a uniform vision of what prosperity means, and the end of a linear and evolutionary developmental vision, makes it possible to focus on what quality of life actually means for a given community.

Many experiments have been performed in the development of Prosperity analysis tools (Sender et al., 2020). In this sense, the Legatum Institute created a ranking of Global Prosperity among countries, analysing the variables security, economic quality, governance, business environment, individual freedoms, social capital, education, health, and environment (Legatum Institute, 2020).

Moore (2015), while recognizing the merit of the UN Sustainable Development Goals in establishing standards and timelines for implementation, points to the need for more goals to be created considering the necessary diversity and contextualization of Global Prosperity, which calls for a change in the concept of wealth, values and social progress.

Thus, we have sought to assemble the elements of gamification for the educational purpose of generating skills necessary to understand the complexity of decisions in a teaching-learning context that thinks of Global Prosperity. Lopes and Oliveira (2013) and Alves (et al., 2015) define this type of gamification as serious game.

2 Methodology

This research is of the Design Science type. This term highlights the orientation, which goes from the development of knowledge to the design of solutions for real-world problems, and the tools necessary to perform appropriate actions attributable to professionals. In this case, a game that helps the teacher, in a management context in higher education, to develop specific skills in their students, in particular the ability of superior thinking based on the reflection of multiple decision-making possibilities.

Sordi, Meireles, and Sanches (2010) state that the process of using knowledge to plan and create an artifact, when it is carefully, systematically, and rigorously analyzed about the effectiveness with which it achieves its goal, can be called Design Science and applied in research in Administration.

In the present case, the game developed from this research is characterized as an artifact systematically developed from an iterative process of constant validation. Venable (2006) proposes a framework for the procedures of Design Science research, shown in figure 2

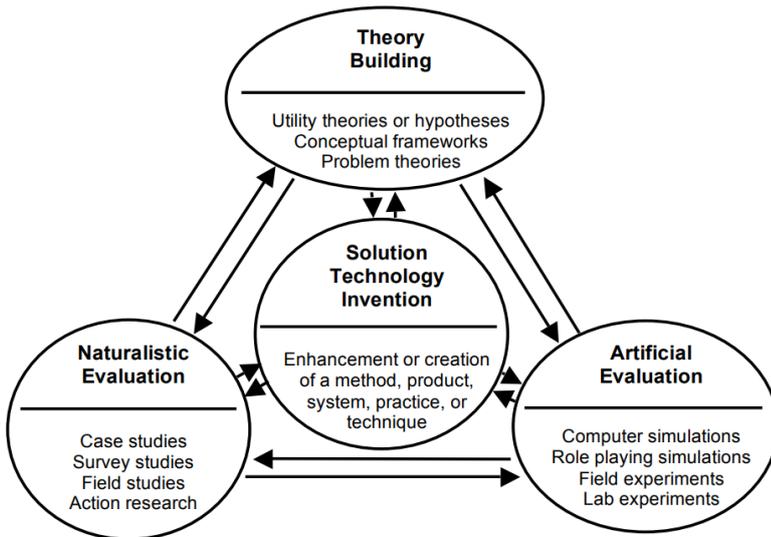


Figure 2. Framework for the Design Science research. Source: Venable (2006).

In figure 2, problem and solution are placed in the same flow, where it is possible to confront them to propose new theories or hypotheses. Although the activities can be developed without a theoretical definition, during the progress of the building-development-validation process, the theoretical construction occurs when analyzing the interactions to understand the problem, its causes, and consequences; when defining and testing the artifact and; with the validation of the results obtained by its application.

Based on figure 2, by Venable (2006), we can divide the research into 3 phases: building, natural or artificial evaluation, and development. It is important to highlight the circular model of the system, a beneficial feature in model validation.

The building stage seeks to understand how it is done, how it should be done, and the success parameters that are adopted in the literature. For this, the basis of the work is theoretical, making the test versions of the game into conceptual work frameworks, trying to create a solid base in which the educational principles of the game were fostered.

Based on this, there are changes made from an evaluation; whether artificial from a role-playing simulation or even simulations from action research, when researchers are involved in adaptation meetings; or even, field studies, as in tests with subjects brought from outside the research.

The results of this iterative model, even if partial in this process, already denote a "design research", while the result of this type of research can be either the finished artifact or an improvement in an artifact that exists, or is in development.

2.1 Serious game Reis Magos

The game Reis Magos was inspired by the teaching case Reis Magos Hotel. It portrays a decision-making situation involving a manager, regarding the fate of an important landmark for tourism, in addition to being a historical and cultural monument in the city of Natal, in Rio Grande do Norte.

Throughout the case, data demonstrating the golden years of the Hotel are shown, followed by changes in the places, due to the expansion of tourism to other regions of the city, and the consequent period of decay of the hotel.

In the teaching case, the student is in the position of the manager, owner of the establishment, and is faced with quantitative and qualitative data related to historical, cultural, economic, and social issues surrounding the hotel, as well as possible choices.

From these reflections and ideas, there was an interest in the use of gamification. This originated discussions regarding its applications, bringing important regional and cultural aspects, and a complex vision of a phenomenon commonly analyzed and decided in favour of profitability and efficiency at any cost, including in the actual outcome of the case in question.

2.2 Structuring of the artifact.

According to the method for the construction of a Design Research, explained by Venable (2006), the three revision phases must occur circularly until the artifact requirements are reached.

The building phase, with the insertion of some authors of more current methodology and references, was basically conducted during the preparation of the Teaching Case and also in the review of the concepts for the construction of the reference, detailed in the session of the Theoretical Elements of this work.

Having partially overcome the building phase, given its restriction of format, the evaluation and development phases started. To facilitate the organization of this phase, it was divided into three equivalent fronts, implemented during developer meetings based on design thinking: ideation, prototyping, and testing, that is, every meeting occurred iteratively in the construction of what the game would be.

It is important to emphasize that the entire evaluation and development process happened in the context of the pandemic. Thus, all steps were performed in weekly meetings at distance with the support of online software as Google Meet.

Regarding ideation, it can be considered a natural assessment, as the researchers were immersed in the process of developing ideas that would contribute to the construction of an initial prototype.

The requirements adopted in the ideation phase were that the game should supply the need to continue the Teaching Case; have at least 3 activities, an interactive one, a collaborative one, and a reflexive one, that led to pondering about the implications of their actions in the game; it should provide conditions for students to develop skills for complex thinking from the theory of global prosperity; and have a graphic representation that alludes to the elements of the Teaching Case (the Hotel and the City).

The part of the meeting that included prototyping can also be considered a natural assessment, since the developers were creating, modifying, or even improving the result of the ideation phase, in the form of the operationalization of rules, mechanics, and educational objectives.

In the testing phases, there were two types of experiments:

Internal tests, which took place periodically, with the developers themselves. A member would always act as a tutor, conducting the activity, due to changes in rules and new mechanics. This role was fundamental, mainly at the beginning.

External testing was on-demand, as soon as we had a first viable prototype that met the requirements. Due to social distancing, we have performed it at the student residence where one of the researchers lived. Other researchers observed this test by video conference software. Both types of testing can be considered artificial evaluations. One of role-playing (internal), and a field study (external).

The main contributions of artificial evaluations were given in 3 dimensions: Game Communication, Mechanics, Resource Balance.

Regarding game communication, contributions to initial information on the map helped in the preliminary communication for those who did not yet know the main rules of the game. As well as the inclusion of the location of the Hotel helped players to create reference and empathy with the city and its culture. The standardization of nomenclatures, such as "turns", "acts", and "resources".

As for the mechanics, the inclusion of more interactive parts, such as the exchange mechanics were important in two points: in the creation of a collaborative environment and the balance of points, when in an environment

conducive to these exchanges, whether due to the scarcity or abundance of a resource. Another contribution to the mechanics was the inclusion of luck or bad luck.

In the balance of features, the main factor that led to this fundamental part of the game design was the repetition of internal tests. The importance of repetition in identifying biases concerning resource imbalances was easily identified when viewing the annotations made in the tests.

This way, we need to understand what the structural elements that the game implemented in its development were, and then move on to their description.

3 Describing the structural elements of the game

Prior, the developers intended to make the game as interactive as possible, thus, characteristics common to Role Play Games (RPG) were used, where the player assumes the role of a character, which has its own history, characteristics, and motivations.

In this way, the game presents the narrative of the characters through three cards distributed throughout the gameplay, they contain a description of motivations and objectives, from the characters, about what should be done with the Hotel. This is also the first contact with the character. This aims to convey a point of view, where the player can identify or not with the motivations, generating or not an empathetic link with the character.

As the game progresses, the player receives information about what happened to the Hotel, from its construction to the most current moment in the case, along with other points of view on what should be done with the organization. This qualitative information ends up influencing the decisions of the winner, as in that moment the player can use the information along with their persuasion skills to defend the point of view from their character, winning the game or not.

During the internal validations, the developers noticed that the main moments where the motivation was highest were at the beginning of each act, when players receive a new card related to their character, delving deeper into their narrative and, with it, they received a letter presenting the historic moment of the Hotel, generating a broad vision of the period in which they are inserted.

In addition to the beginning of the acts, the end of the game also represents a peak of motivation, as the strategy chosen by the player is put to the test and everything, they learned during the game can be used as an argument in his defence in defining the winner.

As this is based on a true story, the demands for resources vary a lot between the possible decisions of what will be done with the Hotel, so the researchers have chosen to divide them into 4 types, to measure the objectives within the game, namely:

1. Monetary Resources: they represent how resources related to money or goods are needed for players to reach their individual goals;
2. Social Resources: they represent how much of the social demand must be met for players to reach their individual goals;
3. Media resources: they represent how many media-related activities players need to reach their goal;
4. Political resources: they represent how much political influence players need to achieve their goal.

These features are directly linked to the individual goals and narratives of each character, being part of one of the main factors of gamification, which is the transformation of actions or events into resources, and thus motivating players to seek the most demanded resources to achieve their goals. Finally, diversifying strategies from each of them according to their demands.

3.1 Introducing the Reis Magos

The game starts with the delivery of the character sheet (figure 3), in this image we can see, in the upper left corner, the individual goals of the character, each one represented by a symbol. From top to bottom: monetary resource, social resource, political, and media resource.

The name of the character is right above its image, and, in the text, part of the story is narrated, which will have a close relationship with the established goals. During the game, the resources acquired by each player must be counted individually, for this it is recommended to use a notepad to manage them.

To prepare the cards, the developers used some popular board games as a model. Pandemic and Monopoly were the main examples; thus, the cards are also one of the attractive aspects of the game. The software's used was Microsoft word, PowerPoint and Excel to organize the texts and the cards design.



Figure 3. Businessperson card. Source: Venable (2006).

As inspiration for the design of the map, the researchers chose the game map from The Godfather board Game, where each region has its resources and characteristics, in this way each area has its peculiarities and, with this, players must create their strategies considering these factors.

At first, the researchers chose the regions closest to the Hotel location to be present in the game, however, during the development stage, demands from the group emerged so that all regions of Natal were present on the map, aiming to represent less privileged regions of the city (figure 4).

At the beginning of the game, only areas 1 and 2 were available for players to select, each one has the number of moves relative to the number of players, i.e., 3 players 3 moves. The move consists of selecting one of the empty circles and placing your piece in it, receiving the resources available there. The number of vacancies in each area is the same as the number of players.



Figure 4. Map of the game.

The game has 4 types of cards, they are used to distribute resources, give bonuses or penalties, while they are also the main narration device of the case.

The resource cards (figure 5) have some resources and tell a little about the history of the Hotel, this information is read to all players and can be used as an argument for defining the winner:

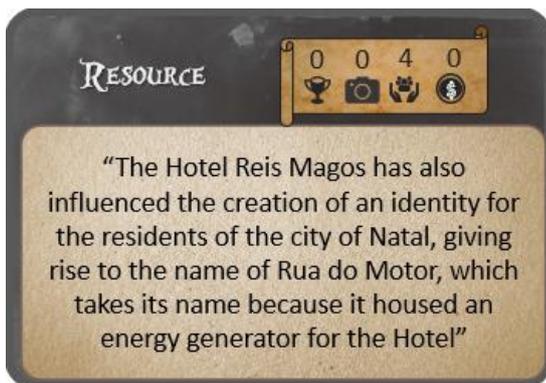


Figure 5. Resource card.

In addition to the businessperson cards (figure 3), presented at the beginning of the game description, there are Act cards (figure 6), which report the historical period in which the game takes place, representing the time of the game advancing.



Figure 6. Act cards.

Finally, there are the luck or bad luck cards (figure 7) aimed at randomly giving bonuses or penalizing players.

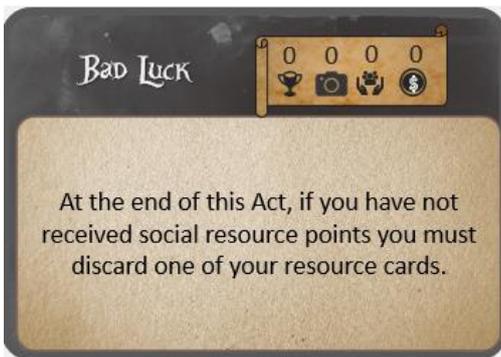


Figure 7. Luck and bad luck cards.

There are game moments to help players achieve the goals from their characters, at the beginning and end of the third act when players can make cards exchanges. As the resources are part of the cards, when an exchange occurs, the previous resource is lost and the new one is received.

The winner of the game is decided in three moments, the first is the strategic evaluation, where each player presents their cards and checks whether they reached their individual goal. After that, each player who did it must defend, in a coherent way, dialoguing with the information he obtained during the game, the reasons why his character deserves the victory, and which benefits will be brought both to the Hotel region and the city of Natal.

Following the presentations, all players must vote to define the winner. If the result is not yet determined, an external person (the teacher, tutor, or a person chosen by the players) must hear the defences presented and decide the outcome.

After the winner is announced, everyone should read the epilogue cards (figures 8 and 9) related to the character, keeping in mind that each card has a prerequisite written on it. After this, a joint reflection should be made as to whether this was the best option for the future of both the Hotel and the city of Natal. This moment serves to develop a critical view of the social issues that are inherent to the Hotel case.



Figure 8. Epilogue cards 1 and 2.

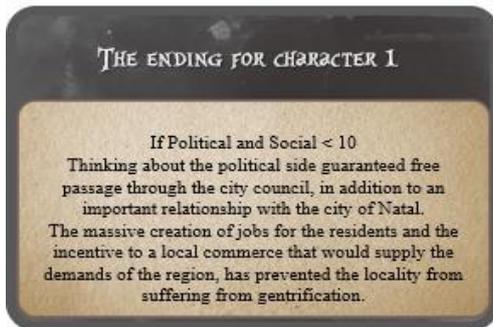


Figure 9. Epilogue card 3.

4 Conclusion

We believe that the objective of this research, which was to describe the development of a serious game to assist in the teaching-learning of global prosperity from tests with Design Science, was achieved. We could see that with Design Science methodology, constant modifications and tests were performed, enhancing the construction of the game and providing changes that have improved its overall quality.

Another contribution of the study is highlighting the concern that developers or educators should have about game elements during development: Communication of game elements, Mechanics, Balance of Resources.

We believe that research is relevant both for theory and the educational process, as well as for business practice. This is demonstrated in the possibility of building games from teaching cases, thus contributing to the development of people through the dissemination and adoption of the combination of these two methodological teaching strategies.

We recognize that the study had limitations. Despite the game being built, it was not tested with a large sample, only remotely, due to the pandemic. In this sense, we suggest further testing performed by studies with large samples, in quantitative research, and, in addition, new research conducted in person.

5 Final considerations

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The use of Kahoot! to promote Active Learning in Port Management and Operation subject in Civil Engineering degree

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Abstract

Port Management and Operation subject in Civil Engineering degree of the University of Alicante is a mainly theoretical subject, full of complex engineering terms. In addition, the schedule of this course is from 15 to 17 h, just after lunchtime. This causes a decrease in the attendance and motivation of the students throughout the course. To mitigate this problem, an Active Learning methodology was proposed. Personal response systems are mechanisms with a system of controls that, in real time, can be used to carry out questionnaires and interpret the results. One of these systems is the platform Kahoot!. The materials of each lesson were provided to the students so that they could work on the contents before the sessions (flipped classroom). A quiz is completed before and after each session to determine the degree of involvement of the students and the level of attention during the session. The first and last 5-10 minutes of each of the theory sessions were dedicated to the Kahoot! quizzes. Most of the students' connections were made with their mobile phones. The results show that the level of student engagement increases over the course, as the percentage of correct answers before the explanation increases over the course. It is also observed that after the lessons, the rate of correct answers increases, which indicates that the students are more involved and follow the class with greater interest than previously. Moreover, gamification improves the classroom learning atmosphere. The use of Kahoot! to promote active learning, to reinforce the knowledge of the concepts seen in class and to create an evaluative test in the form of a game were evaluated in a very positive way.

Keywords: Active Learning; Civil Engineering Education; Kahoot!; Soft Skills.

1 Introduction

Teaching in Spanish faculties generally involves a large number of students, whose active participation in classes and evaluation involves great difficulties (Pérez-Colodrero, 2020). Thus, one of the main problems in university teaching nowadays is the lack of motivation and participation on the part of the students (Pintor et al., 2014). The subject of Management and Operation of Ports of the Degree in Civil Engineering at the University of Alicante, although it has few students, there is a lack of motivation among them.

At the beginning of the 21st century, the first personal response systems appeared to alleviate this problem. These were initially called "clickers", which are mechanisms with a system of controls that, in real time, can be used to perform questionnaires and interpret the results (Pintor et al., 2014). One of these systems is Kahoot! platform. This platform is a personal or group response system that, based on the game, transforms the teaching-learning process (da Silva et al., 2018). In this way, students learn from a playful perspective (Jaber et al., 2016), their motivation, commitment and active participation are fostered (Sharples, 2000; Wang, 2015) and, at the same time, digital competence is developed (Álvarez-Rosa et al., 2018).

The recreational component of these games promotes student motivation, confirming the existence of a relationship between gamification and motivation (Kenny & McDaniel, 2011). Therefore, if one of the main objectives is to increase the motivation of students to achieve meaningful learning (Curto Prieto et al., 2019), games present a good opportunity to increase the motivation, desire and commitment of students in their teaching-learning process (Serrano et al., 2011).

Some educators consider game-based learning an effective method because it maintains the purpose of education, enhances player skill, and can be used in real life (Von Wangenheim & Shull, 2009). In fact, gamification has increased exponentially in education since 2014 perhaps because educational games put the learner at the centre of learning, which facilitates more fruitful and interesting learning (Torres-Toukoumidis et al., 2019). Therefore, the introduction of games in class aims to foster dynamism, engagement and motivation

among other factors (Lee & Hammer, 2011). But the current educational landscape demands the inclusion of technological advances to improve the quality and the learning process, which would be in line with the preferences of the millennial generation for more active and technological (Jain & Dutta, 2019).

Considering the benefits described above, this methodology has been implemented in the course of Port Management and Operation of the Degree in Civil Engineering at the University of Alicante to achieve the results obtained in similar studies in the scientific literature described for this resource. Thus, it is expected to improve the participation, performance and motivation of students in the subject, mainly in the theoretical part of it.

2 Method

This project was conducted within the framework of the course "Management and Operation of Ports" of the Civil Engineering Degree of the University of Alicante. This compulsory course is part of the fourth year of the degree within the branch of Transport and Urban Services. It is a subject that consists of 1.20 credits of theory, 0.60 credits of problems and 0.60 credits of fieldwork. The inclusion of the Kahoot platform was implemented in the 2018-2019, 2019-2020 and 2020-2021 courses of the subject of Port Management and Operation of the fourth year of the Degree in Civil Engineering at the University of Alicante. The experience evaluated a total of 14 students (6 in 2018-19, 4 in 2019-20 and 4 in 2020-21) during the theory hours shared between two professors every Wednesday of the second term from 15:00 to 17:00.

In this research, the Kahoot! platform was used to evaluate the level of attention, understanding and involvement of the students, both in their work at home and during the theoretical classes. This platform allows for questionnaires that can be answered individually or in groups, and also allows setting a time limit for answering the question. Students earn points for each correct answer as well as for the speed with which they answer the different questions correctly. For students to participate in the surveys, they must have a device connected to the network. It is not necessary to have an account on the platform application, simply know the test code and indicate a name or "nickname" to identify yourself during the duration of the questionnaire. When the time to answer each question is over or when all the participants have answered, the answer selected by each contestant, the correct answer, the score obtained in that question by each participant and the positions in the ranking are displayed. Finally, at the end of the questionnaire, it is possible to include questions to obtain feedback on the feelings of the students.

In our case, the tests were set to be answered individually by each of the students. Each test had a different number of questions depending on the length and complexity of the unit. The response time was set at 20 seconds for all cases. To determine the degree of enjoyment of the students in taking these tests, four questions were established only in the last test that was taken. The questions indicated the level of enjoyment valued between zero and five, the belief of having learned with the method (yes or no), the possible recommendation of the method (yes or no), and the level of satisfaction with the methodology, with the possibility of answering between zero to five.

On the first day of class, the procedure and teaching methodology that would be used during the theoretical classes of the course was explained. It was indicated that during each session two questionnaires would be conducted on the Kahoot! platform, one at the beginning and one at the end of the session. During this first class, a first test was carried out to find out the knowledge that the students had about the subject.

Throughout the following sessions, the first and last 5-10 minutes of each theoretical class were reserved for the completion of the questionnaires with the Kahoot! platform. This is because in each class two questionnaires were carried out with two purposes.

1) Before the theoretical explanation (BTE Test). Before the explanation of each lecture, a test was conducted with questions related to the topic. This made it possible to know the level of knowledge of the subject of the students, as well as their work at home and involvement with the subject since at the beginning of the course the theoretical development of each of the topics and their organization and distribution throughout the course were given.

2) After the theoretical explanation (ATE Test). After the explanation of the topics corresponding to each session, a test was conducted with repeated questions from the initial test and other new questions, but all of them related to the topic of the session. The purpose of this test is to determine the level of attention, motivation and learning of the students throughout the class.

Once all the students had answered each of the ATE test questions, the answers chosen by each one were commented on and discussed, and the correct answer was reasoned. At the end, the teacher of the session kept the results obtained by the participants in each session.

Finally, during the last session, the initial test (conducted on the first day) was repeated to see the increase in knowledge of the students concerning the beginning of the course.

3 Results

The first result to be analyzed is the results obtained by the students after the inverted class, that is, the previous evaluation of the knowledge of the students before the explanation of the unit in class. It should be born in mind that the students had all the information on the subject from the beginning of the course. Figure 1 shows the average results obtained by each of the courses evaluated for each of the 14 theoretical class sessions. As can be observed, in general, the percentage of correct answers before the theoretical explanation is between 54% and 71%, with an average of 61.6% in the three courses. Unit 10 stands out for its low percentage of correct answers, with an average of 45.7% in the three courses. It is also observed (except for unit 10) that the percentage of success in the last units tends to increase slightly, which leads to thinking that little by little the students tend to become more involved in the readings and learning of the material before the explanation in class. Next, the success rate of the students after the theoretical classes is evaluated. In this case, the percentage of correct answers is higher than in the questionnaires before the explanation in class, which implies a high level of student attention during the theoretical sessions. In this case, the percentages of correct answers are between 61% and 95%, with an average of 79.4% in the three courses. Once again, unit 10 stands out with an average correct answer of 85.5%, which implies an increase of 87% concerning the percentage of correct answers before the theory class (the average for the rest of the units is around 26%). This leads to the conclusion that this is a complex topic for students to understand unless they are correctly guided during its development.

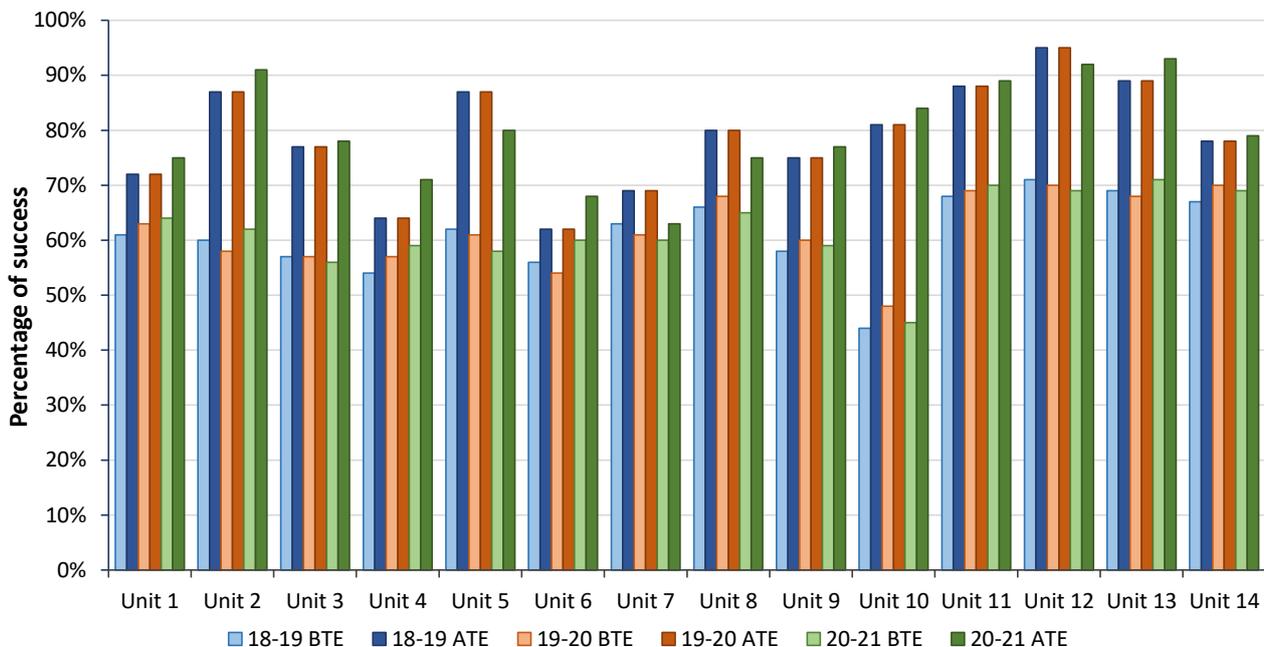


Figure 1. Percentage of correct answers in each of the Kahoot! questionnaires conducted in each of the courses analyzed before (BTE) and after (ATE) the explanation of the subject unit.

Figure 2 shows the results of the test conducted on the first day of class to determine the level of student knowledge of the subject. As can be seen at the beginning of the course, knowledge is very low with an average

of 57% of the answers being correct. This is due to the high degree of specialization of the subject, the contents, and the vocabulary used in the port environment. However, the knowledge at the end of the course as observed is much higher with an average of 85% of the questions answered successfully. These good results were also reflected in the final grade of the course, which increased by 1.8 points concerning previous courses in which the usual methodology was used.

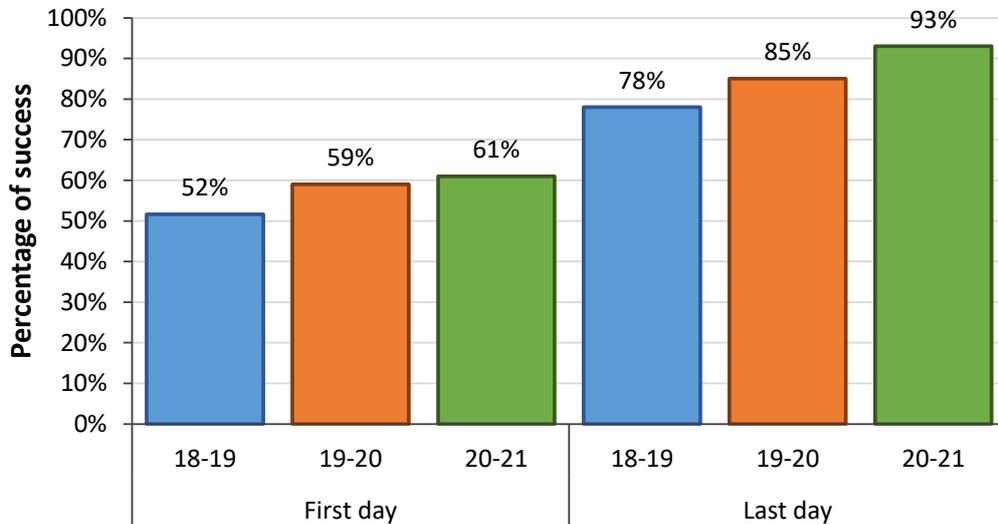


Figure 2. Results of the initial test conducted on the first day and the last day of class.

The analysis of the four final questions to determine the degree of student acceptance of the Kahoot! platform (Figure 3) shows that in general, 89% of students consider this learning system to be innovative, fun and motivating in the classroom. The 2020-2021 course is the one that least values the platform as learning dynamize with 79% compared to 85% in 2018-2019 and 2019-2020. Analyzing the questions individually, it is observed that 87% of the students consider that it is a fun way of learning, highlighting the course 2019-2020 with 91%. Interestingly, the same percentage (87%) of students consider that they have learned using this methodology and that they would recommend it. The percentage of 2020-2021 stands out with only 81% in the question on whether they have learned something, while the 2018-2019 and 2019-2020 courses present 93% and 88%, respectively. Finally, concerning the question of the level of satisfaction with the methodology, only 79% of the students said that they had a positive feeling. The 2018-2019 and 2019-2020 academic years stand out again with 73% and 71%, respectively, while the 2020-2021 academic year shows the lowest percentage with only 63%.

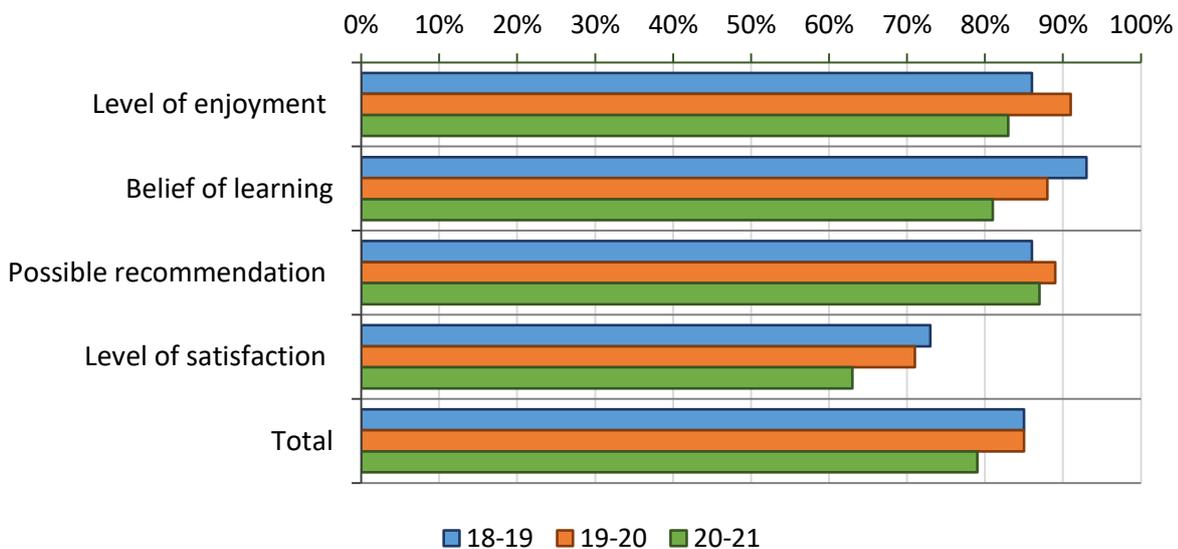


Figure 3. Responses to the questions to determine the degree of acceptance of the use of the Kahoot! platform for each of the implementation courses.

4 Discussion

Several studies have shown that the performance of students in class increases at the same time that their motivation increases (Ausó-Monreal et al., 2020; Sousa, 2016). This seems to be in line with the results obtained for two reasons: i) the final grade of the courses in which Kahoot is applied as a dynamic tool increases considerably concerning the courses in which it is not used, and; ii) the success rate of the students in the different questionnaires increases throughout the sessions (Figure 1). The subject of Management and Operation of Ports is within the subjects of transport and urban services so that, in general, students do not show a great interest in this subject (outside the usual scope of this branch), which can be deduced from the low average grade obtained. However, in the years in which the methodology of using the Kahoot platform has been implemented, the average grade has increased by about two points.

The motivation of the student cannot be based solely on the teaching methodology, but the teaching staff plays a very important role (Fernández, 2002; Torelló, 2011). For example, the students in the last course where Kahoot is applied (2020-2021) have the worst opinion of the platform of the three courses analyzed (Figure 3), and yet they are the ones with the highest average grade of the eight courses studied. Nevertheless, this group of students considers that the platform helps them in learning (Figure 3), which is consistent with the results obtained in other similar studies (Ausó-Monreal et al., 2020; Rodríguez-Fernández, 2017). The difficulty of the subject matter can also influence student motivation. Thus, in general, the students can understand and assimilate about 60% of the subject by themselves, while a dynamic and enjoyable explanation by the teacher makes the percentage of success reach almost 80%. In addition, in unit 10, the explanation provided by the teacher increases the percentage of correct answers from 45.7% to 85.5% (Figure 1). Curiously, the success rate in the test on the first day of class (57%, Figure 2) is approximately the same as the final average grade achieved by the students when the Kahoot! platform was not used in teaching.

Another factor that, according to different authors, can affect the degree of attention is the moment in which the subject is taught, such as the day or time of the session (Blake, 1967). In this sense, it can be affirmed that this factor has not influenced the results obtained since the beginning of the course, which has been taught on Wednesdays from three to six o'clock. Finally, to correctly evaluate the real attention level of the students in the program, it would be necessary to conduct the questionnaires every fifteen minutes, because as indicated (among others) by Sousa (2016) throughout the duration of a class, the attention of the student varies, being on average about 15-20 minutes (Bunce et al., 2010). However, this is not feasible given that the length of the units and the organization of the subject do not allow this time to be wasted throughout the class.

5 Conclusion

With all the results obtained in this work, it can be concluded that:

- The flipped classroom allows students to achieve a success rate of about 60% (BTE test), approximately equal to the final grade obtained by students without Kahoot!
- The explanation of the subject matter by the teacher and the use of Kahoot! increases the success rate to 80% (ATE test).
- Student motivation increases throughout the course when using Kahoot!, as demonstrated by the increase in the success rate.
- Some units cannot be understood by the students on their own, and the explanation of the concepts by the teacher is necessary for their correct assimilation.
- In general, students consider that the use of the platform is fun, increases their level of learning and would recommend its use.

To continue increasing the use of the platform, it is necessary to conduct a study on the response time, since some of the students indicated that, although the recreational part motivated them to study the subject, the pressure of having little time to answer the questions made them nervous and stressed them out.

6 Acknowledgements

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Entrepreneurship as a tool to facilitate job placement for civil engineering students

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Abstract

Traditionally, civil engineering professionals have worked for public institutions and large construction companies. Nowadays, recent graduates of civil engineering have problems finding their first job despite the requirements of the degree. Creativity, collaboration, persuasion and emotional intelligence are the essential soft skills needed. Unfortunately, none of them appears in the civil engineering curriculum.

This work proposes to conduct the creation of small cooperative teams of students to face different challenges in line with the syllabus of one or several subjects. Thanks to this, students can increase the number of competencies developed during their academic life at the university. Nevertheless, they are able to apply technical knowledge while they gain professional experiences, improve their soft skills and enhance the ability to understand, use and manage their own emotions through active learning. Incorporating real-life technical problems, already solved or not, from different companies is the key to establishing alliances with enterprises that connect hard and soft skills. In this way, the quality of the grade can be improved while the students keep learning key competencies of the subject allowing them to gain skills and professional experience. Furthermore, this activity can be the beginning of a start-up in an academic environment.

This research has shown the need for the development of soft skills in civil engineering students, both undergraduate and master's degrees, to promote entrepreneurship and self-employment as job opportunities. The creation of the teams, their management, the resolution of the different problems from real-life situations or adapted, the connection with different companies and institutions and the presentation of the results can be the key to the holistic development of future professionals. Including the possibility of entrepreneurship, since all the students questioned considered that they have improved their entrepreneurial competencies thanks to this experience.

Keywords: Active Learning; Engineering Education; Entrepreneurship; Start-Up; Soft Skills.

1 Introduction

Both the current and future generations of civil engineers will not find it sufficient to assimilate the curriculum content related to the technical knowledge of road design, dam maintenance or port management. Unemployment rates among civil engineering graduates are on the rise and there are more and more civil engineering schools. Therefore, it is necessary to introduce knowledge related to entrepreneurship as well as the development of soft skills as a differentiator for the subsequent employability of graduates.

An important aspect to justify this need is the unemployment rate of close to 5% in the year 2020 along with the low rate of Spanish university graduates who develop their professional activity from self-employment (Garcia-Barba et al., 2020). Furthermore, the European Union has set as a strategic objective within the ET2020 document "Increasing creativity and innovation, including entrepreneurship, at all levels of education and training" (Weber, 2012). Therefore, this innovative action is understood and explained within this objective. Also considering, entrepreneurship is a complex and extensive process ranging from the generation of the idea, the process of elaboration and maturation of the idea, the output to the real world, as well as the evaluation of the process to complete the action performed.

From a formal point of view, there is more and more research and in-depth study of the phenomenon of entrepreneurship and the concept itself, and most developing and developed countries are now beginning to clearly link entrepreneurship education and training (Matlay, 2008). It is clear, as already mentioned, that the concept of entrepreneurship education is much broader than just entrepreneurship training content. As Osorio and Duarte (2011) state, economic sciences have a functional view, of what to do; human sciences focus on the

subject, they are interested in who and why; whereas management sciences apply to the process, how. We can complete the definition of the concept of entrepreneurial activity as the management of radical and discontinuous change, or strategic renewal regardless of whether this strategic renewal occurs within or outside existing organisations, and regardless of whether it results in a new business (de Haro et al., 2019).

Of course, as Timmons (2003) suggests, the myth that entrepreneurs are born has evolved, leading to the consensus that entrepreneurship, like any other discipline, can be learned. If we delve a little deeper, entrepreneurship includes the study of the sources of opportunities, the processes of discovering, evaluating and exploiting opportunities, and the people who discover, evaluate and exploit them. Entrepreneurship does not require, but may include the creation of new organisations (Shane & Venkataraman, 2003). Furthermore, we should understand these entrepreneurial competencies as "the set of knowledge, skills, abilities and aptitudes necessary for the effective work of an individual in a specific work environment" (Savanevičienė et al., 2008). Entrepreneurship should therefore be approached holistically by acquiring the set of competencies and we can understand it from Social Learning Theory (Bandura, 1987), the individual's attention is directed towards the entrepreneurial phenomenon, instilling certain knowledge and skills to be able to create entrepreneurial activity, which facilitates and supports the emergence of entrepreneurial behaviours. Although the observation method is not the only approach to internalise and reproducing these behaviours (Arriaga et al., 2006). For instance, learning by doing is one of the keys to the development of these entrepreneurial skills (Lăcătuș & Stăiculescu, 2016).

The aim of this research is to evaluate the influence that the development of entrepreneurial projects has on the development of soft skills for entrepreneurship in students, as well as the improvement of the results in the subject itself by carrying out a realistic and viable project. Students to promote entrepreneurship and self-employment as job opportunities. The creation of small cooperative teams of students to face different real-life challenges while they keep learning key competencies of a subject will improve their soft skills and professional experience, including the possibility of entrepreneurship as a tool to facilitate job placement thanks to having an integral vision of the project and not only a technical one. Even, in the future, they will be able to identify any project as a business opportunity.

2 Method

2.1 Context and student profile

This experience was implemented in the subject Maritime Traffic and Port Operation, optative framed in the first four-month period of the second year of the Master's degree in Civil Engineering, during the academic year 2020-21 and 2021-22. The purpose of this subject is to familiarize and train students in the understanding of the knowledge derived from maritime traffic and port operations. The course is carried out through theoretical and practical lessons on problems with practical cases related to maritime traffic and port operations. It has 3 credits ECTS: 1,20 Practical credits and 1,80 Distance-based hours. The entrepreneurial project is fully developed during the first quarter of the second academic year of the Master.

The students of Master's degree in Civil Engineering have a deeper understanding of the multiple constraints of technical and legal nature arising in public work construction. Moreover, it is designed to boost their ability to use proven methods and technologies in order to achieve greater efficiency in public work construction. In addition, the students who are attending this course have already passed subjects in the civil engineering degree that previously develop the basic knowledge to create entrepreneurial projects, such as *Engineering and Business*, *Works for organisation and occupational health and safety* or *Urban planning and environment* (Table 1). Therefore, they should already be able to tackle the professional world of civil engineering and the construction business.

2.2 Description of the experience

The aim of the experience is to develop teamwork to solve an open problem so that students are able to adopt a creative and innovative solution ensuring sustainability from an economic, financial and technological point of view. The problems or projects to be solved are connected to real problems and can lead to public-private

collaboration, thus allowing the creation of a learning environment that leads to the development of skills and attitudes in the profile of civil engineering students.

Through the entity that manages the ports of Valencia, Sagunto and Gandía, the Port Authority of Valencia and the Open Innovation Hub of Valenciaport, a series of real challenges will be established that must be solved as sustainable projects from an integral point of view. The Port of Valencia is also one of the leaders in container transport in the Mediterranean Sea, reaffirming itself as well as "strengthening its leadership position as a reference and strategic hub of the Mediterranean in the management of goods and traffic, its commitment to sustainability and the environment, digitalisation and transparency". Therefore, each academic year will include a series of challenges related to the sustainable mobility of people and goods, the development of a competitive offer of infrastructures and services, as well as the fight against climate change. In short, the aim is to develop solutions and business models to achieve a smart, green and resilient port in the future (Figure 1). The different development proposals should be connected to the items given in Figure 1, related to circularity, planning, management and operations. In this way, we connect the development of entrepreneurial ideas considering social and environmental aspects.

Table 1: Curriculum of the Undergraduate degree in Civil Engineering at the University of Alicante. In bold are the subjects that previously develop the basic knowledge to create entrepreneurial projects.

FIRST-YEAR	ECTS
FUNDAMENTALS OF MATHEMATICS IN ENGINEERING I	6
FUNDAMENTALS OF PHYSICS IN CIVIL ENGINEERING	6
FUNDAMENTALS OF CHEMISTRY IN CIVIL ENGINEERING	6
FUNDAMENTALS OF INFORMATION TECHNOLOGY	6
ENGINEERING AND BUSINESS	6
FUNDAMENTALS OF MATHEMATICS IN ENGINEERING II	6
MECHANICS FOR ENGINEERS	6
GRAPHIC EXPRESSION I	6
FUNDAMENTALS OF MATHEMATICS IN ENGINEERING III	6
GEOLOGY APPLIED TO CIVIL ENGINEERING	6
SECOND-YEAR	
STRUCTURAL ANALYSIS I	7.5
CONSTRUCTION MATERIALS I	6
GRAPHIC EXPRESSION II	7.5
HYDRAULICS AND HYDROLOGY	9
SOIL AND ROCK MECHANICS	6
FURTHER MATHEMATICS	6
STRUCTURAL ANALYSIS II	6
CONSTRUCTION MATERIALS II	6
TOPOGRAPHY AND PHOTOGRAMMETRY	6
THIRD-YEAR	
GEOTECHNICS AND FOUNDATIONS	6
ELECTRICAL TECHNOLOGY AND LIGHTING ENGINEERING	6

CONSTRUCTION PROCEDURES AND MACHINERY IN PUBLIC WORKS	6
URBAN PLANNING AND THE ENVIRONMENT	6
METALLIC STRUCTURES	6
REINFORCED AND PRE-STRESSED CONCRETE STRUCTURES	6
WORKS ORGANISATION AND OCCUPATIONAL HEALTH AND SAFETY	6
+COMPULSORY SUBJECTS: PUBLIC WORKS, HYDROLOGY OR TRANSPORT AND SERVICES	18
FOURTH-YEAR	
FINAL PROJECT	12
+COMPULSORY SUBJECTS: PUBLIC WORKS, HYDROLOGY OR TRANSPORT AND SERVICES	48

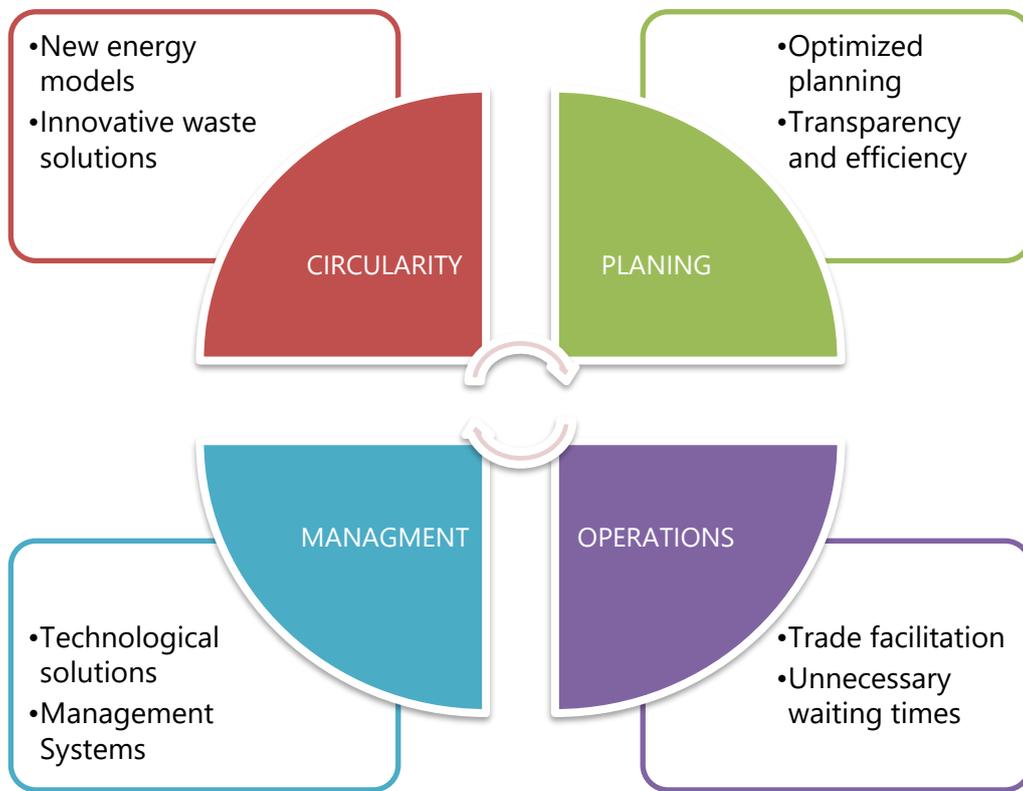


Figure 1: Challenges in which the different projects will be included

The development of the entrepreneurial project can be structured in four steps (Figure 2) It begins with the presentation of the challenges for the academic year. After the first phase of research on the different proposals by the teams, the choice of the problem or project is made.

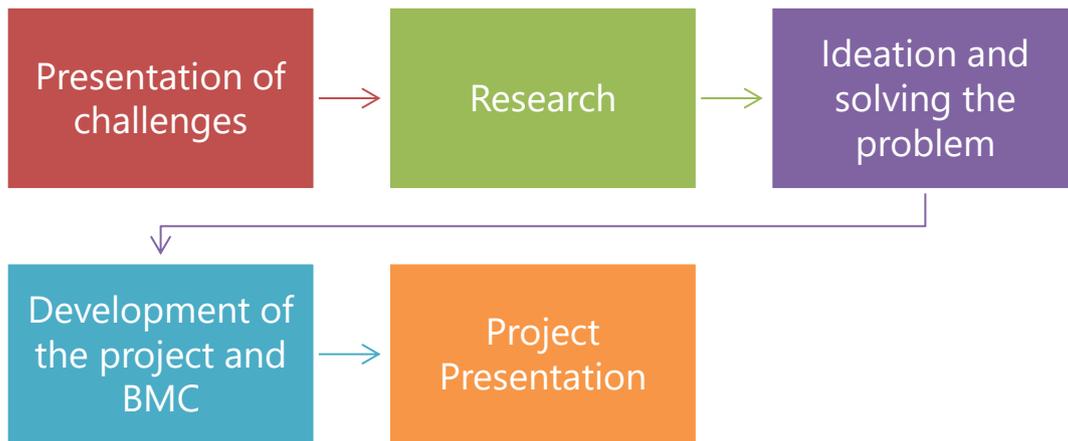
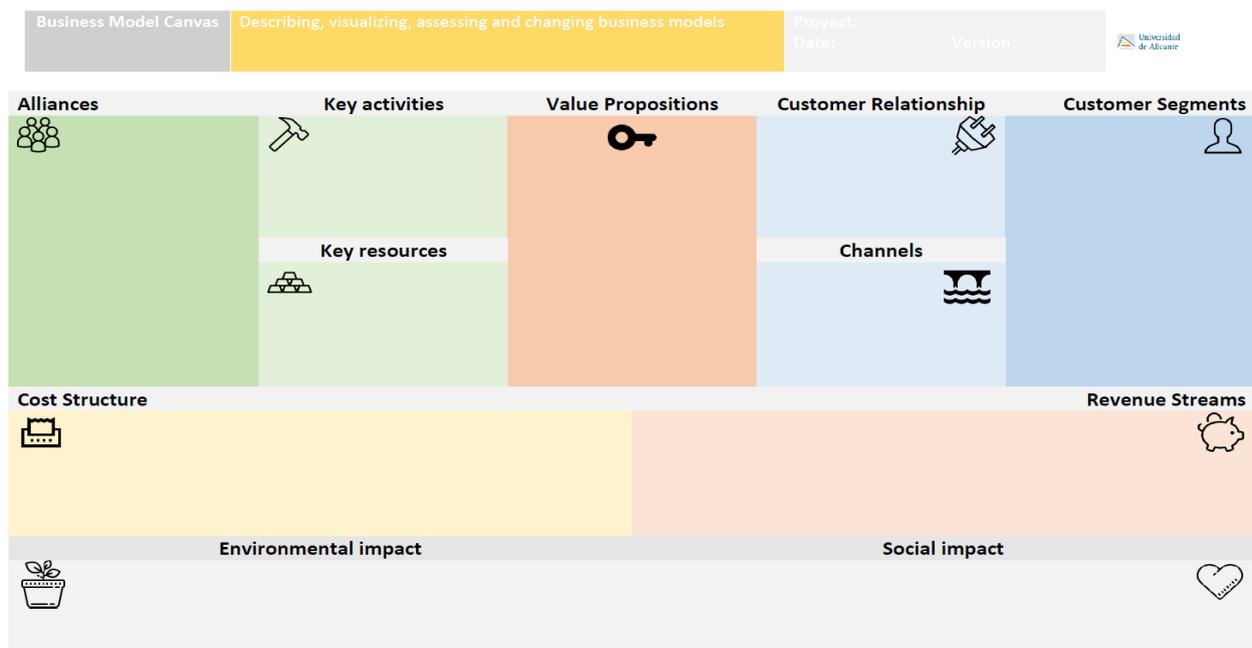


Figure 2 Steps of the entrepreneurial project

The next phase has to do with the part of in-depth research of the problem, academic and professional review of the subject studied and the ideation of proposals that solve the problem with the characteristics mentioned.

The following step is related to the realization of the ideas generated in the previous stage, the development of the project from the technical point of view and the application of the Business Model Canvas (Figure 3). It resolves aspects such as the value proposition, or what our solution brings to the table that is different from what was being done before (Osterwalder & Pigneur, 2010).



Abstract:

Figure 3: Business Model Canvas adapted for the entrepreneurial project.

Moreover, it considers the customer segment or, depending on the type of project, the different users. It also includes the relationship established with the customers and how our solution reaches these users. This document reflects the activities and key resources that are necessary for our proposal to work as well as the possible alliances that can or should be established for it to work properly. Finally, it considers its economic balance, both in terms of costs and revenues. We will also include the social and environmental impact of the project itself. In this way, students solve the proposed problems from a technical point of view but are able to understand their economic feasibility. Thus, they can understand how their solution would work from a business point of view, giving it the form of a business idea and almost a business plan, one of the first steps to entrepreneurship through this model. Finally, the project is presented for its evaluation both by the teachers

of the course and by the organizations or entities that have proposed the issues and problems to be solved in order to assess both from the technical and academic point of view the different solutions provided.

2.3 Evaluation

For the global evaluation of the Project, not only concerning the given solution but also to measure the whole development of the project from an integral point of view, the following evaluation rubric is proposed for the different teams that carry it out, establishing the score from 0 to 10 and determining a weight percentage of influence of the value of each item, being the final grade the weighted grade (Table 2).

Table 2: Evaluation rubric for the evaluation of the Project.

n	%	Item
1	10	Problem characterization and data collection with a supporting methodology
2	10	Data analysis and generation of results lead to conclusions in the development of the project.
3	10	Evaluation of the problem from multiple perspectives including the connection between different areas and disciplines.
4	10	Demonstrate a comprehensive understanding of the problem to be solved, based on critical thinking and creative solutions.
5	10	Teamwork, effective management and learning through failure.
6	30	Appropriate, innovative and creative technical solution
7	20	Effective presentation and communication of the proposed solution or project

The rubric was developed by researching the best practices found in Weber (2012), in Lăcătuș and Stăiculescu (2016) or Garcia-Barba et al. (2020). Therefore, for the design of the rubric we have considered a holistic view of the development of the project and weighted those items according to the importance they may have when carrying out another successful entrepreneurial project.

In addition, to evaluate the degree of achievement of the objectives regarding the development of soft skills with the realization of the project by the participants, a short questionnaire of satisfaction was carried out with the evaluation of the following questions from 1 to 5, being 1 not at all and 5 very much:

- Have you improved your ability to work in a team?
- Have you improved your conflict resolution skills?
- Have you improved your ability to communicate ideas and concepts?
- Have you improved your ability to adapt your ideas?
- Have you improved your creative capacity and strategic vision?

3 Results

The first aspect to highlight is the positive feedback from the students during the term from a qualitative point of view. All of them have expressed the great practical application of the work proposed for the course and the possibility of using different knowledge from other subjects in the development of the project itself, as well as giving a practical approach to the resolution of the practical part of the course. During the realisation and subsequent defence of the project they work on the five main competences measured. For example, the development of teamwork throughout the whole four-month period, adopting different roles during the project. Creativity and strategic vision to provide solutions to the problems initially posed, as well as the integral conception of the project so that it is technically and economically viable. The ability to communicate, both with colleagues, teachers and collaborating companies, at different levels, is important for the project as well as the resolution of conflicts implicit in any project contextualised in the real world. As I mentioned, these five competences are key to developing an entrepreneurial attitude and valuing entrepreneurship as a job opportunity. Secondly, the average grade of the participating students has improved considerably. The improvement concerning the last academic year without implementation was 16 % (2020-2021) for the first year with the new methodological proposal and 18% for the second year of implementation (2021-2022).

(Figure 4). Students are involved in the subject and the development of the projects by carrying out a realistic, feasible project designed to simulate a future professional activity.

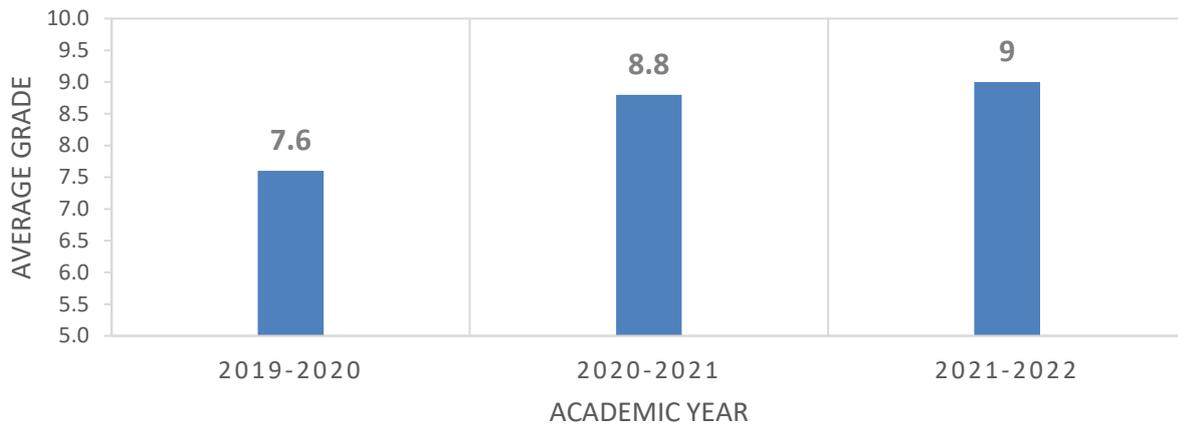


Figure 4. Average grade of the subject for the last three academic years

Finally, the measurement of the results of the perception of the development of soft skills shows the improvement experienced in the last course concerning them. The assessment of the questionnaires shows that the students have experienced the development of these skills (Figure 5).

Communication and Work in teams were the soft skills more developed, followed by a significant level of Creativity and strategic vision. Conflict resolutions and adaptability of ideas were the lesser evaluated skills, but both with a score of 3.8/5.

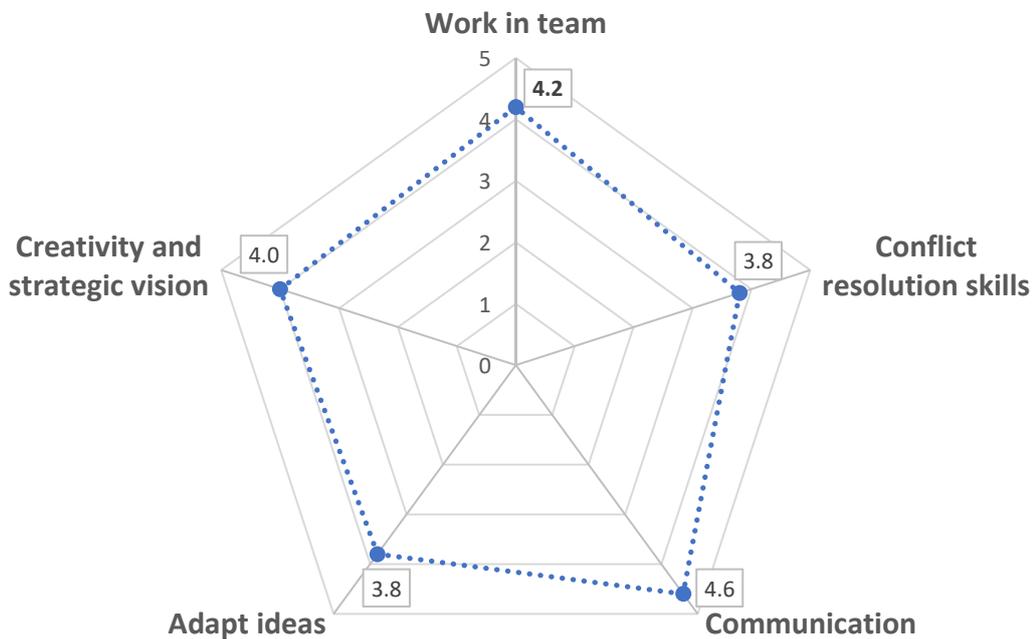


Figure 5. Mean of the responses to self-assessment questionnaire competencies

4 Conclusions

This research tackles the need for the development of soft skills in civil engineering students, both undergraduate and master's degrees, to promote entrepreneurship and self-employment as a job opportunity, since recent graduates have problems finding their first job. Creativity, collaboration, persuasion and emotional intelligence are the essential soft skills needed.

This work developed a strategy to improve soft skills through the creation of small cooperative teams of students to face different real-life technical problems, establishing alliances with leading companies in the sector and connecting hard and soft skills in line with the syllabus of Maritime Traffic and Port Operation of the Master's degree in Civil Engineering at the University of Alicante.

The results show that by working on the concepts related to the subject, these soft skills can be acquired and developed, becoming more attractive to students. This is reflected in the increase in the average grade of the subject after applying this methodology. Thanks to this, students can increase the number of competencies developed during their academic life at the university.

Finally, it is worth highlighting the usefulness of this work methodology, since all the students consider that they have improved in the entrepreneurial competencies evaluated by means of the self-assessment questionnaire. Therefore, we consider this activity a success as it has improved the job prospects of our students and can also be the beginning of a start-up in an academic environment.

5 Acknowledgements

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Use of video tutorials for Active Learning and PBL in Coastal Engineering subject

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Abstract

In the past, workshops lessons on the Coastal Engineering subject were held in computer classrooms, where different problems related to the subject were resolved. The professor guided the students through each of the sessions, while at the same time the students solved them on their computers, asking any questions that arose and, finally, completing the tasks individually, either in the classroom or at home. However, this methodology usually presented serious difficulties to students, particularly the impossibility in some cases to follow the synchronised rhythm of the explanations, which led to a reduction in attendance and a drop in academic performance. To improve it, a teaching model based on Active Learning and Project-Based Learning (PBL), supported by of Information and Communication Technologies (ICT) resources, was proposed. Students now acquire the competencies by carrying out their vulnerability analysis projects. Audio-visual material (video tutorials) recorded by the professors solving a case of study in a guided way, covering the computer sessions were created and shared. Students therefore can view those videos asynchronously as many times as necessary, using the device that suits them best (TV, computer, tablet or mobile phone) at the same time as they carry out their work. The practical sessions are now dedicated to the development of a vulnerability analysis project. Assignments and supplemental materials from instructors keep learners engaged and accountable. The results obtained show an increase in attendance and follow-up of the computer sessions, as well as a reduction in the drop-out rate of the subject and an improvement in the quality of the project submitted by the students at the end of the course. In addition, an increase in academic performance and global students' satisfaction has been detected.

Keywords: Engineering Education; Video Tutorial; Computer Lesson; Project-Based Learning.

1 Introduction

The development of the European Higher Education Area (EHEA) has led to updating the teaching methodologies traditionally used. Its implementation has implied a real educational innovation in the use of more active teaching-learning methodologies, supported by the special relevance of Information and Communication Technologies (ICT) as a systematic resource to help improve the training process of the students (Cañete et al., 2012). The number of hours of autonomous work required for students to assimilate the contents developed is explicitly stated in the methodological planning of each subject, contained in the corresponding teaching guide. As Aguila et al. (2013) indicate, in order to facilitate the autonomous work of students, there may be a multitude of curricular material available on the Internet (notes in digital format, exercise resolution, guided computer practice, video tutorials, etc.) that adapts to the learning pace of the students, without time restrictions, and that allows reinforcing and complementing the contents developed in the classroom lessons, promoting the acquisition of knowledge, skills and professional competences. Similar experiences have been succeeded developed in the field practices sessions with success (Pagán et al., 2021).

The Active Learning and Project-Based Learning (PBL) methodology have been implemented in recent years in different European degrees and universities, especially in the field of engineering (Lehmann et al., 2008). Compared to traditional lectures, this new approach offers several advantages: on the one hand, students have a leading role in on-site sessions, increasing their motivation and satisfaction. On the other hand, active methodologies and ICTs are naturally incorporated into learning processes, and various transversal competencies can be developed and assessed in the classroom (Zabalza et al., 2016). In this methodology, learning is organised through a real problem or project proposals. The problem or project is the starting point of the learning process, and its resolution involves integrating contents and procedures in a learning activity,

facilitating a better understanding of the contents of the subject and working on their application to real situations (Lehmann et al., 2008). Its main characteristics are:

- It focuses on the development of projects whose characteristics are often defined by the students themselves, based on guidelines and main aims set by the tutor.
- The project is presented at the beginning of the process, becoming the guiding thread of the learning process, developing the students' competencies. Thus, the concepts, procedures and attitudes included in the learning objectives of the subject will be assimilated.
- Learning activities are carried out in teams, in a collaborative and active environment among students.
- There is continuous monitoring of student learning, both at the group and individual level, encouraging critical reflection, self-assessment and co-assessment, with the tutor acting as a guide and advisor in the process.
- It involves the development of specific skills and abilities, such as leadership, the capacity for coordination, consensus, decision-making, communication skills, and the sharing of roles and responsibilities.
- These abilities and new skills are acquired through active learning.

For this purpose, video tutorials are a key ICT resource that makes it easier for students to learn the contents (Colomo & Aguilar, 2017). Video tutorials can be reproduced as many times as the students require, stopped during playback to repeat a specific part, and viewed from anywhere on computers, TVs or mobile devices depending on the needs of the students, which makes the video format an essential resource for offering quality training (Brame, 2016). The duration of video tutorials is an element of discussion (González et al., 2010). While some experiences have been developed during a traditional practice session lasting between 1h - 1h 30min, capturing the screen using specific software and recording the audio with the teacher's explanations and the doubts or questions that arise for students during the practical session (González et al., 2010), most focus on the development of videos specifically to support lessons. Knowledge pills allow access to concrete information very quickly, but with the restriction that their content is very limited and, therefore, their learning activities are very targeted. The availability of a good collection of short videos as part of the didactic material of a subject, made available to students, allows them to execute and consume them autonomously as a training complement, thus improving the effectiveness of knowledge transfer (Alonso-González et al., 2021).

This research focuses on the development and implementation of strategies and methodologies in the implementation of formative assessment in practical subjects, assessing them based on objective quality criteria, such as academic results, and subjective criteria like the anonymous opinion collected from students and their own experience of the teaching staff throughout its implementation. Specifically, a new methodology is proposed for the development and evaluation of the computer sessions on the subject Coastal and Oceanic Engineering for the Degree in Marine Sciences at the University of Alicante. The incorporation of new tools in our teaching practice, many of them based on ICTs, will improve the independent learning of students. Thus, the specific objectives to be achieved by this teaching experience are the following: (i) to investigate the different resources available offered by ICTs for the guided resolution of computer-based practical sessions and project-based learning, (ii) to design materials for the guided resolution of the practical sessions adapted to the subject Coastal and Oceanic Engineering of the degree in Marine Sciences of the University of Alicante, (iii) to implement the use of the designed resources in the teaching of the current course and finally, (iv) to evaluate the results of the experience using the information adequately collected using questionnaires to students.

2 Method

2.1 Context and participants

This educational experience was implemented in the subject Coastal and Oceanic Engineering, which is part of the 4th year of the Degree in Marine Sciences, pursued during the first semester and with six European Credit Transfer and Accumulation System (ECTS) credits. It aims to provide students with the acquisition and application of the necessary knowledge involved in coastal phenomena, as well as in the design and

construction of facilities and engineering works in the maritime and coastal environment. The development of the subject is carried out through theoretical classes, practical problems, computer practice and field visits. In the academic year 2021-2022, there are a total of 18 students enrolled. The computer lessons are conducted over 5 sessions of one hour each, distributed throughout the course so that the concepts learnt during the theory sessions can be applied.

Throughout the sessions, the teacher made an example in class of obtaining the Coastal Vulnerability Index (CVI) on a coastal strip, obtaining the geomorphological, oceanographic and marine community parameters. To do this, he used a geographic information system, QGIS, a new software for students, which can be complex without some previous knowledge. The students were, at the same time, doing their work on their computers, asking questions and, finally, completing the tasks autonomously, either in the classroom or, in most cases, at home, given the lack of time to complete them in the classroom due to the slow pace of the explanations. Moreover, students usually complained about the impossibility in some cases to follow the synchronised rhythm of the explanations, which led to a reduction in attendance and a drop in academic performance.

As a method of evaluation, at the end of the course the students must hand in a report describing the procedure followed and the results obtained from the calculation of the CVI. The mark obtained represented 10% of the total of the course.

2.2 Description of the experience

Firstly, a design phase was carried out in the initial weeks of the course and before the start of the computer-based practice sessions. All available information on Active Learning and PBL, supported by ICT resources, was compiled. After exploring the different methods and resources available (notes in digital format, existing videos on the Internet, creation of specific video tutorials, etc.), scenarios for testing new methodological tools and innovative techniques for improving the teaching-learning processes were developed and implemented. The aim is to achieve greater student engagement, which should have a positive impact on the results of the continuous assessment throughout the course.

The best way to implement the PBL and Active Learning methodology was discussed among all the participants in the network, and the conclusion was to carry out group workshops on obtaining CVI in different sectors of the coast. Professors met to establish the quantity and appropriate content of each of the video tutorials necessary to carry out this experience, in line with the development of the contents of the subject and with the programming of the computer-based practices foreseen in the schedule. Two video tutorials were created containing the guided development of the computer exercises, with the step-by-step resolution of a practical case of obtaining the CVI in a coastal stretch different to those assigned to the groups. For each video tutorial, files were prepared with the title, description, contents, format and duration, as well as screenshots of the cover and part of the video (Figure). In addition, to reflect the real workload, the weight of this part of the course has been increased to 30% of the total mark, with 60% for the report to be submitted with the methodology and results obtained and 40% for the presentation and oral defence of the project carried out.

For the evaluation of the experience, the instrument to be used will be mainly a questionnaire designed to find out the students' assessment of the new methodology implemented and the video tutorials, including possible answers where appropriate. Moreover, we will also compare the attendance and the results of the evaluation of the current academic year in which the experience will be implemented with the reports of previous years.

As described above, the new methodology based on PBL and Active Learning has been implemented in the academic year 2021/22. The students will carry out a project in groups of between 2 and 3 people whose objective is to obtain the Coastal Vulnerability Index of various stretches of coastline of similar length and complexity. Sessions 1, 3 and 5 will be done in classic workshop lessons, while for sessions 2 and 4 the viewing of the video tutorials is implemented.

This activity was planned to be carried out asynchronously, although it was recommended to be carried out before the date assigned to the respective sessions in order to be able to dedicate the session (1 hour each) to the resolution of doubts and/or problems that arose for each student. The video tutorials have been created with the OBS Studio software, and have been published on Youtube with access only to the students' e-mail

addresses. This platform was chosen for its versatility and accessibility from different devices (PC, Tablets, Smartphones, TVs...) as well as for providing higher quality viewing and for being widely known by all students, regardless of their digital skills.

TITLE: Shoreline evolution analysis using QGIS 3.20		TITLE: Obtaining the Coastal Vulnerability Index – CVI – with QGIS 3.20	
DESCRIPTION: Video tutorial with guided resolution of the process of obtaining and analysing the evolution of the shoreline from aerial images, as well as obtaining change statistics, using QGIS 3.20		DESCRIPTION: Video tutorial with a guided resolution of the process of obtaining and analysing a coastal vulnerability index, using QGIS 3.20	
CONTENTS: <ul style="list-style-type: none"> • Description of the software and working environment. • Downloading and opening of orthophotos. • Shore line and dune foot vectorization. • Base line vectorization. • Creation of shoreline and dune surfaces. • Creation of transects. • Obtaining evolution statistics. • Sedimentary budget. Erosion/Acretion zones 		CONTENTS: <ul style="list-style-type: none"> • Definition of CVI. • Geomorphological variables. • Hydrodynamic variables. • Vegetation variables. • Definition of vulnerability ranges. • Obtaining the CVI in QGIS 3.20. • Creation of maps with the results. 	
FORMAT: .mp4 4K video	LENGTH: 48:38	FORMAT: .mp4 4K video	LENGTH: 50:39

Figure 1: Sheet describing the video tutorials

Finally, after the implementation of the experience, the degree of student satisfaction was evaluated using the evaluation instrument described in section 2.2 above. To ensure maximum participation, a 10 min slot was set aside at the end of the last practical session where all the students were present and were asked to fill in the questionnaire anonymously. Once the answers were collected, they were analysed to draw the results and conclusions shown below. In addition, an evaluation was made of the overall quality of the work presented in comparison with that of previous years, as well as an analysis of academic performance and attendance and monitoring of the practical sessions.

3 Results

It is important to highlight the high participation of the students in answering the questionnaire, achieving 100 % participation. This was influenced by the fact that a few minutes were spent in a class in which all 18 students were present and asked to fill in the questionnaire, emphasising its anonymous nature.

The results of the questions asked are shown below. Inquired about their opinion on the use of PBL & video tutorials (Figure 2a), 100 % of the students considered their use to be of interest, as well as that it has helped them in the learning process. As for the teaching methodology (Figure 2b), 89 % opt for the one followed in this course, viewing the videos asynchronously at home before the workshop session and dedicating that hour to progressing with the assigned work and resolving doubts. Only 2 student indicates that he/she prefers to receive a classic synchronous explanation and to have the videos as support, while not having the video tutorials is an option that nobody chooses.

Regarding the reasons why the students consider that the methodology implemented in this course (video tutorials for the guided resolution of computer exercises and PBL) has improved the learning process (Figure 2c), all indicate as advantages of having the video tutorials that when developing the project, they have been able to consult the explanations again, that they have been able to repeat the explanations as many times as they have needed and that in this way it has become easier to follow the course at their own pace. 78 % percent consider that this gives them more time to understand the exercises proposed, and only 61 % see the advantage of the video tutorials as being able to follow the explanations if they do not attend the workshop in person.

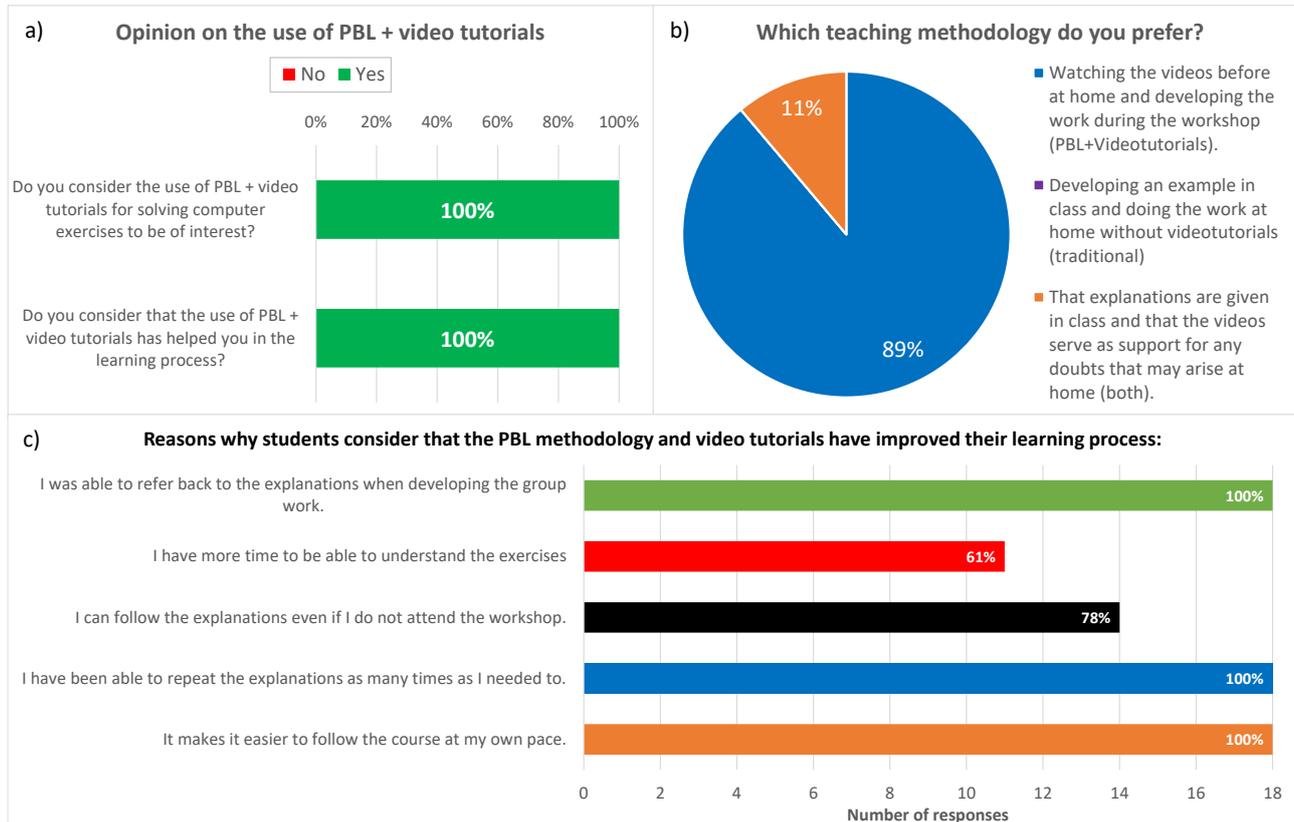


Figure 2: Responses on the use of video tutorials and PBL methodology

Regarding the perception of how the video tutorials influence the consolidation of the concepts and knowledge explained (Figure 3a), 63 % consider that they influence Very, while the remaining 38 % indicate that they influence them Extremely. In other words, all the students considered that the use of video tutorials had a positive or very positive influence on the teaching-learning process. When asked about the aspects that they consider most relevant to be present in the video tutorials and that help them to learn (Figure 3c), 100 % agree that the accuracy of the explanations is the most relevant, followed by 78 % who mark the graphic design as an aspect to be considered, and only two students indicate that the clarity language used is relevant. This implies that the students attach importance to receiving correct and precise explanations, and also to the graphic format of the video, whereas they dominate the technical terms used by not giving them so much importance.

About the advantages they have observed in the use of video tutorials in the learning process (Figure 3c), the students could choose multiple predefined answers, as well as add other advantages that they considered were not present, which none of them did. The only answer that everyone ticked, and which is therefore shown to be the greatest advantage of this methodology, is *Being able to repeat the explanation and the commands used as many times as one needs*. This is followed by *Following the pace of the class in a personalised way* (89 %), and this response corresponds to one of the findings of this research. Traditionally, teachers were faced with the problem of having to adapt the pace of their lessons to students who had more difficulties in following them synchronously or who had less digital skills, causing, on the one hand, that the time allocated to each lesson

was often scarce because they could not advance all the desired concepts and procedures, and on the other hand, that the students were frustrated, causing a reduction in attendance and a decrease in academic performance. At the same time, more advanced students or those with greater digital competencies saw their learning progress delayed, with abundant time-outs that also caused the same effect of disconnection, sometimes even generating some friction between classmates.

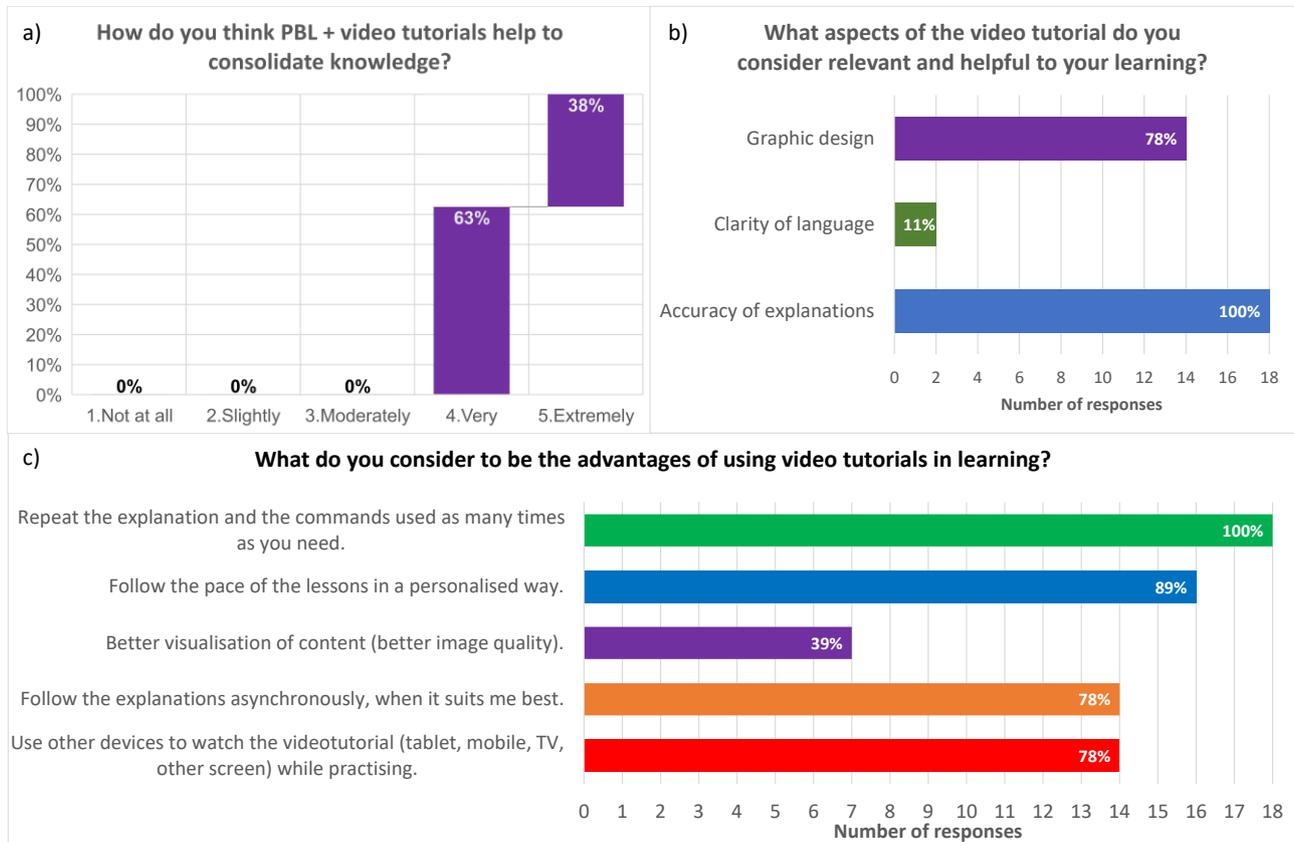


Figure 3: Responses on the advantages and influences of the proposed methodology on learning.

This negative effect has disappeared with the proposed methodology, as viewing the video tutorials allows each student to follow the pace of the explanations they need, even if they are viewed during the workshops, and the teacher can deal with any doubts that arise in a personalised way without slowing down the teaching pace. 78 % of students agree that this is an advantage, since being able to view the video tutorials at any time makes it easier to follow their own pace of learning at the time when they are most inclined. Comments not included in the survey but communicated to the teaching staff by the students indicated that they watched the videos on their smartphones/tablets on public transport on the way to class, during the dead time between subjects or even while doing their housework. This possibility of viewing the video tutorials on several devices is also pointed out as an advantage by 78 % of respondents, as it allows them to have the video tutorial on one screen to follow the explanations and on the other screen to carry out the procedure at the same time. Finally, the better visualisation of the content, an aspect that also used to be problematic in workshops sessions, due to the resolution of the projector, is only indicated as an advantage by 39 % of the students.

The length of the video tutorials was rated as adequate by 72 % of the students, while 28 % considered it excessive (Figure 4a). It should be recalled that the duration of the video tutorials was about 50 minutes, practically the same as the face-to-face session. However, for some students this duration is often considered excessive, as they are used to a faster audiovisual consumption, like knowledge pills (Colomo & Aguilar, 2017). As a proposal for improvement, for future courses we will consider dividing the video tutorials into blocks of a shorter duration (10-15 min). It will be the same content but presented in a more convenient way to find the parts of interest for the students. Even so, 89 % would like to repeat this experience in other subjects (Figure 4b), while 11 % indicate that they might like to do so, which indicates that the methodology we have implemented has been very well accepted.

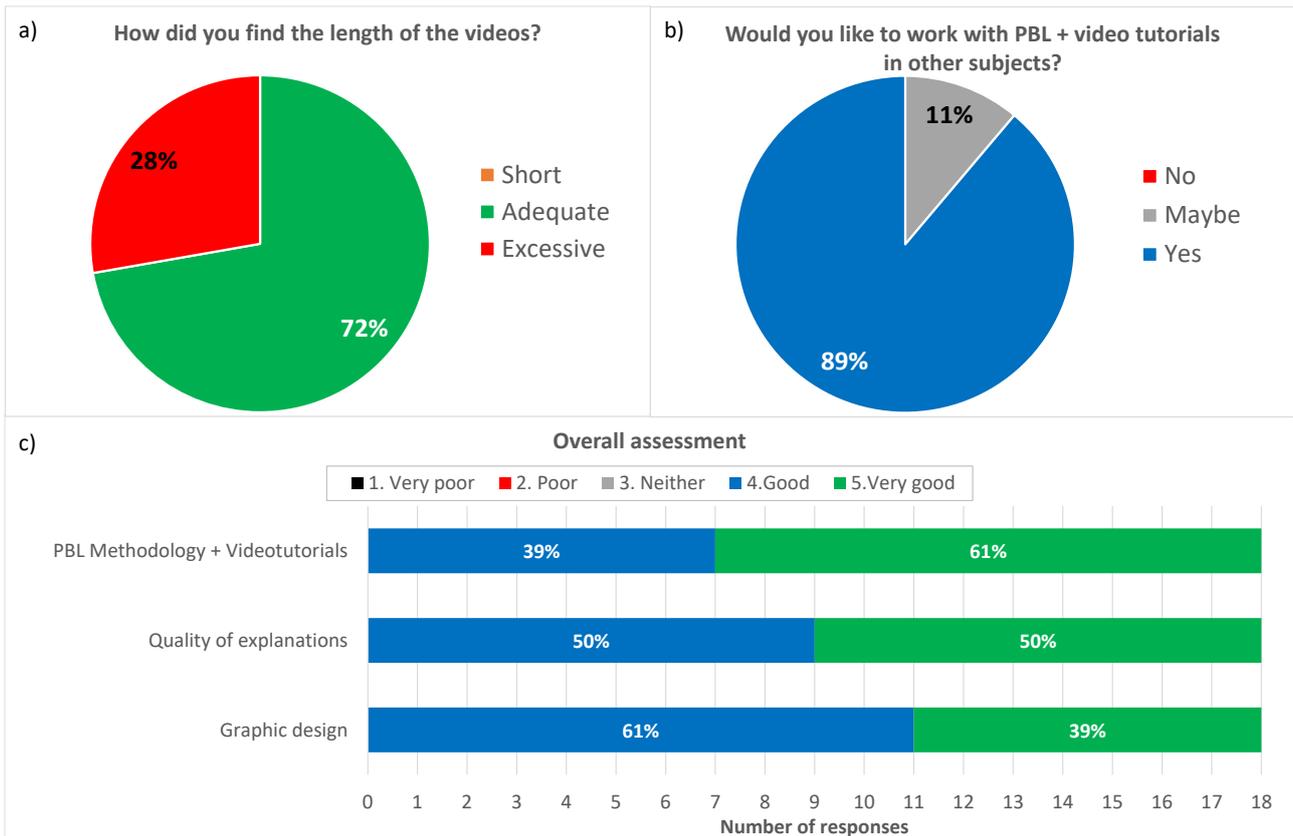


Figure 4: Assessment of the experience.

This is confirmed in Figure 4c, where, when asked about the overall evaluation of the experience, i.e. the learning based on carrying out a project to calculate the coastal vulnerability index with video tutorials that solve the computer-based practice sessions in a guided manner, 61 % indicated that the experience was Very Good, and 39 % that it was Good, with no negative evaluations. The quality of the explanations is rated 50 % as Good or Very Good, while the graphic design of the tutorials is rated as Good (61 %) or Very Good (39 %). In other words, in all cases there is a positive assessment by the students. No negative comments or proposals for improvement have been received from them regarding the experience developed in this course.

Figure 5 show an increase in attendance (100 % in this academic year 2021-22), as well as an improvement in the quality of the project submitted by the students at the end of the course, even considering the quality requirements were higher than previous courses as the value of the final mark of the workshop on the overall subject score was augmented up to 30 %. In addition, an increase in academic performance has been detected, obtaining the best scores of the last 7 academic courses.

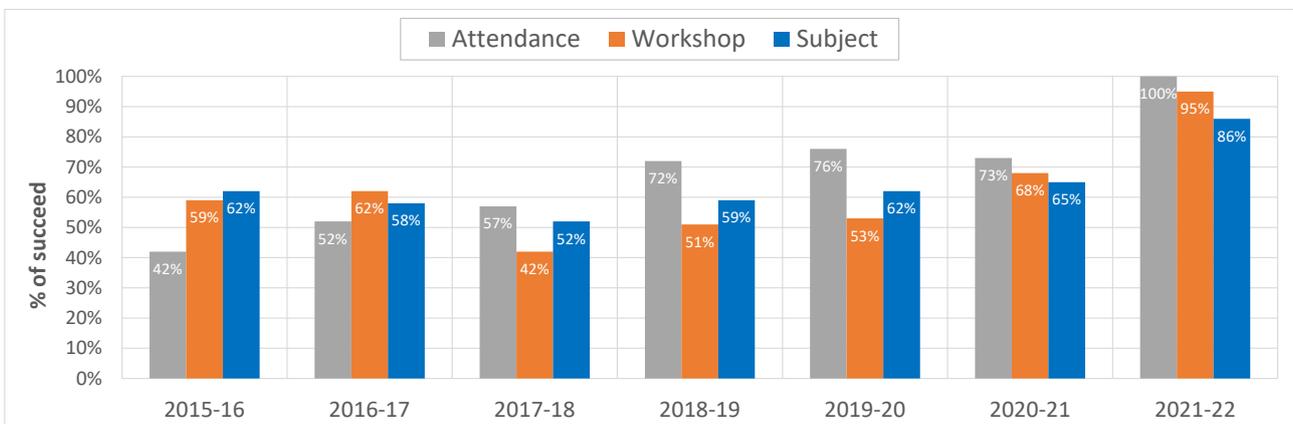


Figure 5: Evolution of the percentage of attendance and success at workshop and overall subject score. Students enrolled were 16, 17, 15, 19, 18, 16 and 18, respectively.

4 Conclusion

This research has investigated the different resources available offered by ICTs for the guided resolution of computer-based practical sessions and project-based learning. Project-Based Learning (PBL) and Active Learning methodology were implemented, creating two video tutorials for the guided resolution of the computer sessions adapted to the subject Coastal and Oceanic Engineering of the degree in Marine Sciences of the University of Alicante. The results obtained show an increase in attendance and engagement in the workshops, as well as an improvement in the quality of the project submitted by the students at the end of the course. Students pointed out that the greatest advantages of this methodology are, firstly, being able to repeat the explanation and the commands used as many times as one needs. Secondly, following the pace of the class in a personalised way. The PBL approach with video tutorials was also well evaluated as a help to assimilate the concepts, procedures and attitudes included in the learning objectives of the subject. In addition, an increase in academic performance and global students' satisfaction has been detected. Thus, this experience can be evaluated as a complete success, encouraging the teaching staff to maintain in the following academic years and even expanding to other subjects where computer practice is relevant.

5 Acknowledgements

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Strengths and dangers of self and peer assessment in engineering learning. Teachers' and students' perspective

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Abstract

Given the need to use competency assessment systems, a complex problem arises, especially when applying a metric to transversal competencies is intended. In this context, it is possible to use, among other tools, self and peer assessment, so that the first-person perspective of the students is considered among the criteria to quantify aspects that are difficult to measure. Even though it may seem interesting, this strategy is not riskless, at least this is deduced when talking about this topic with some colleagues. It is intended to address a reflection on the advantages of self and peer assessment within engineering assessment, but also analysing the risks involved (lack of maturity, assigning too high grades...). This feeling of risky activity is presented as especially dangerous when it has to be used by teachers who are reluctant to its use. Analysis of collected assessment data and questionnaires addressed to both teachers and students will provide an insight to their opinion about these assessment methods.

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

1 Introduction

A recent study by Halls et al. (2021) suggests that, after a systematic literature review, a greater focus is required in student engagement in the assessment in engineering education. Involving students in the assessment process may provide interesting outcomes. If students are aware of the relevance of their role in the evaluation process, this process can become a true learning opportunity. Even at a professional level, well supported formative feedback would be required to successfully change workplace culture (Willey & Gardner, 2007). This change is initiated by facilitating individual self-reflection and ongoing improvement while encouraging teams to resolve team issues independently. Maybe the most obvious ways to generate this involvement are self and peer assessment.

As stated in (Boud & Falchikov, 1989) self-assessment refers to the involvement of learners in making judgements about their own learning, particularly about their achievements and the outcomes of their learning and is mostly used for formative assessment to foster reflection on one's own learning processes and results (Dochy et al., 1999). Falchikov (1995) defines peer assessment as the process through which groups of individuals rate their peers. This exercise may or may not entail previous discussion or agreement over criteria. It may involve the use of rating instruments or checklists which have been designed by others before the peer assessment exercise or designed by the user group to meet its particular needs (Dochy et al., 1999).

Besides, both students and teachers find risks in the use of self and peer assessment. Some of the potential risks, that are listed in (Tennant & Crawford, 2019), include the reaction of colleagues and external examiners, demands of time, its robustness, and reliability. Students themselves tends to feel confident in traditional summative assessment methods as unequivocally valid assessment mechanisms (Fernandes et al., 2012), considering summative assessment is in the centre of their concerns and as one of the most important results of their learning process.

There are, notwithstanding, studies that conclude that this active role of students in the assessment process is reliable and fair and contributes to a growth in competence (Dochy et al., 1999), even for first year engineering students (Van Hattum-Janssen & Lourenço, 2008).

Summarizing, some of the commonly cited benefits and risks of self and peer assessment for teachers and students are listed in table 1.

Table 1. Benefits and risks of self and peer assessment (literature review).

Implication	Teacher	Student
Benefits	Improves professional practice in relationship with assessment	Improves learning
	Increases opportunities to monitor student progress and identify potential problems	Supports generic skill development
	Strengthens assessment criteria and marking schemes	Enhances motivation and enthusiasm
	Promotes student-centred learning	Increases level of feedback
Risks	Reactions of Colleagues and External Examiners	Belief in teacher-centred assessment
	Time consuming	Time consuming
	Robustness of Assessment	Feeling that traditional summative assessment is more objective
	Reliability	Fears about the impartiality of other students
	Lack of confidence in students' fairness	Relationship with other students if assessment is not favourable

To be honest, when considering that the fact that self and peer assessment can show a lack of objectivity is perceived as a risk for both parts, we are not much worried about this fact. Moreover, some of the members of the network are defendants of subjective assessment as presented in a past work (Romá, 2007).

2 Context

This work is being developed under the framework of a 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 this work is to explore the risks and strengths of self and peer assessment from students' and teachers' perspective together with their feelings in front of that strengths and dangers from a local context, as explained in following sections. Besides, some data is going to be summarized from courses that use, among others, self and peer assessment as a part of their evaluation methods.

In sections 2.1 and 2.2 the context in which the study is being conducted is presented.

2.1 Courses

To analyse the results obtained by the use of self and peer assessment, data from five different courses using these types of assessment in different schemes is going to be used. These are courses from Sound and Image in Telecommunication Engineering (SITE) and Biomedical Engineering (BE) degrees in the University of Alicante Polytechnic School.

Table 2. Use of self and peer assessment in the courses under study.

Course	Year	Self	Peer	Short description
Basic Electronics	1 st	5%	N. A.	General opinion about course and self-performance
Biomedical Signal Processing	3 rd	5%	N. A.	General opinion about course and self-performance
Video Engineering	3 rd	35%	13%	Peer assessment of projects and self-assessment of self-performance (with special focus on transversal skills)
Advanced Audio-visual Systems	4 th	N. A.	40%	Peer assessment of research project and literature review)
Audio-visual Production Facilities	4 th	35%	N. A.	General opinion about course and self-performance

Self and peer assessment are used with different objectives and also with different effects in the final marks of each course. Table 2 summarizes how self and peer assessment is used and their weights in the final course marks. The first course in which self and peer assessment was introduced is Video Engineering (in 2008) and the last one Biomedical Signal Processing (in 2016). The weight in which self and peer assessment affects to the final mark varies from 5% to almost 50% depending on the course design.

Shortly, in first year courses self-assessment is used as a final reflection activity with a modest impact in the final mark. This process is done around two questions, what are the benefits of taking this course and which skills have I developed. In 3rd and 4th courses the self-assessment is used goal-based evaluation in with students have to analyse the degree of fulfilment of transversal skills as stated in course goals.

Using peer-assessment in PBL is interesting as it gives provides students a tool to put their own work in context (especially if all the working teams are trying to solve the same, or at least a very similar, problem).

The data will be used to check if there is correlation between student and teacher appreciation of learning outcomes, and to analyse if students tend to over-grade themselves. As students are asked to deliver justified reports to support the proposed marks, interesting information can be obtained from these reports.

2.2 Perspective

The sources of information to gather teachers' and students' perspective in front of self and peer assessment have been some face-to-face informal interviews (with teachers) and questionnaires sent to both students and teachers. The justified reports mentioned in the previous section will also be used with the purpose of gathering information about students' opinion.

The interviews have been used to collect the general feeling of some colleagues (both using and not using self and peer assessment in their courses). As the questions were intentionally not previously prepared, the goal of these meetings was focused on getting subjective information rather than measurable data.

Students' questionnaire has been sent (sharing a google forms link) mainly to students who are actually enrolled in the courses mentioned in Table 1. The questions have also been sent to students from the Master's degree on Education Research. No personal information is stored to ensuring the anonymity of the respondents. At the moment of writing this report, 60 students have fulfilled the form. Although there is no way to know if the answers come from undergraduate or master's degree students, this is not a key data in the study as we were not looking for correlation between answers and students' affiliation. The first intention was to submit the question only to engineering students, but we finally decided to also include students from the Education Research program. 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 similar form has been sent to teachers from the Polytechnic School and the Faculty of Education, with the following structure: 7 multiple choice questions about assessment in general, 5 about self-assessment, 4 about students' position in front of self-assessment, 5 about peer assessment, 5 about students' position in front of

peer assessment, 2 about final thoughts and one open answer question. Unfortunately, although not surprisingly, only 10 people have responded to the form at this moment.

3 Teachers' perspective

With only 10 people answering the questionnaire, there is, obviously, no possibility of getting statistics from the data. Notwithstanding, some insights can be obtained from teachers' opinion that can be correlated with the answers in the informal meetings. To put answers in perspective, almost any of them had made research or training on self or peer assessment and its effect on learning outcomes.

One of the most cited risks (and reasons supporting the decision of not using self and peer assessment) is its lack of reliability or, in other words, not being objective. In fact, only 20% of answers show tendency for subjective assessment, while the 80% rely on the idea of having an objective assessment method. Surprisingly, 30% of the teachers are not able to say if the assessment methods they are using are summative or formative ones. There is a higher than desirable number of teachers who is still evaluating in the same way they were evaluated without considering other options. As can be seen in Figure 1 most of them have never used self or peer assessment in their courses, so some of the opinions expressed may not being supported by experience.

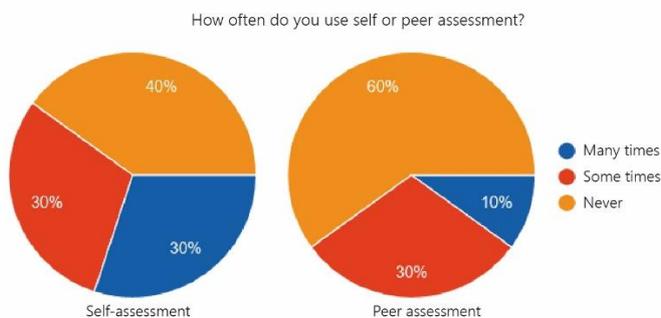


Figure 1. Use of self and peer assessment.

In general, teachers tend to think that students will over-rate themselves when using self-assessment (80%). However, most of teachers think that students are mature enough to carry on with this process (90%). When considering peer assessment there is a slightly lower level of over-rating sensation (70%), while 100% consider that students are able to evaluate their peers in a mature and thoughtful way.

Asking teachers about under what circumstances they will choose self and/or peer assessment in their courses, some interesting answers are listed:

- Reduced number of students and over third year.
- Course content not being too technical (more descriptive).
- I would have to feel that these strategies help student development.
- I would use them if I was responsible of the course or having the support of course responsible.
- Not having to worry about others' opinion.

Our general perception is that teachers who are reluctant to the use of self and peer assessment show a tendency to think that students will not evaluate themselves fairly, even though they consider students to be mature enough to take the assessment responsibility. At the same time these teachers are not aware of the learning outcomes that self and peer assessment can provide.

4 Students' perspective

In this section some of the students' answers to the questionnaire are going to be highlighted. To state a starting point, the answers about the preferred assessment model is presented in figure 2.

Which assessment model do you feel more comfortable with?

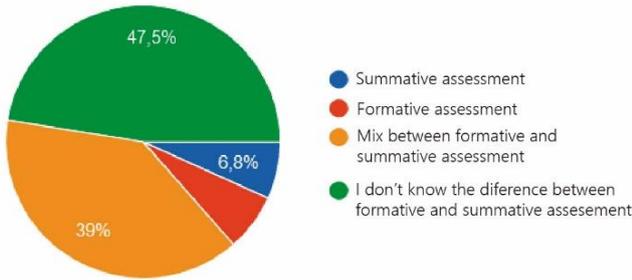


Figure 2. Preferred assessment model for students.

It is remarkable that near 50% of students don't know the difference between assessment models. If we want them to be engaged in the learning process and confident in the way they are evaluated, maybe an effort must be done in letting them know about the assessment strategies.

When students are asked if self or peer assessment must have a considerable weight in the final mark, similar results are found when comparing self and peer assessment (Figure 3). It will be interesting to figure out why over 20% of students fully disagree with the use of self or peer assessment as part of the final mark.

Self or peer assessment must have considerable weight of the final mark

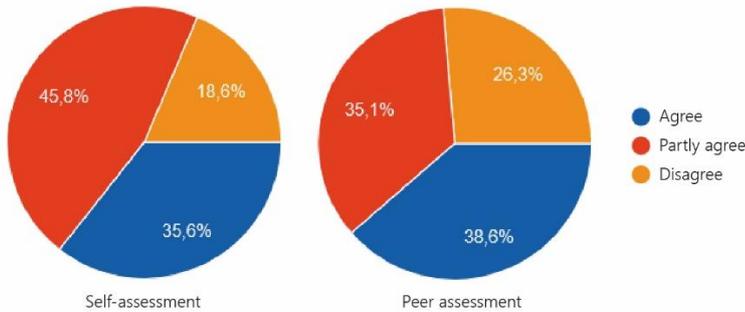


Figure 3. Students' opinion about using self and peer assessment with a considerable weight in the final mark.

Most of the students are aware that proposing self-assessment implicitly shows a high level of confidence in themselves, as can be seen in figure 4.

I am aware that by proposing self-assessment a high level of confidence in myself is shown.

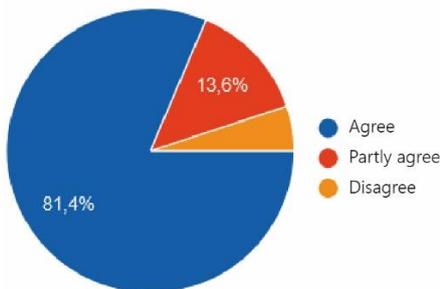


Figure 4. Students' awareness of the confidence needed to propose self-assessment.

When considering one of the fears expressed by teachers in relation with the tendency of students to over-rate themselves, students' opinion is not the same (figure 5).

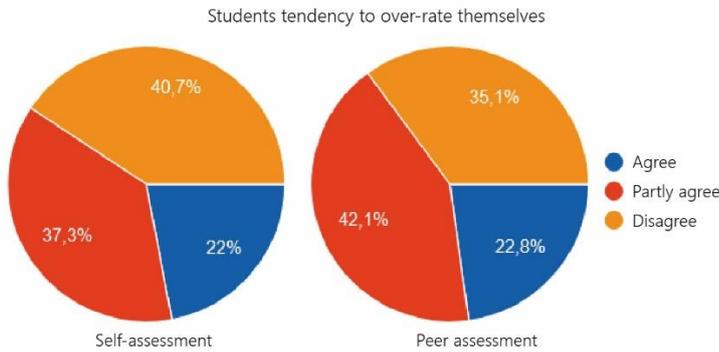


Figure 5. Students' awareness of the confident needed to propose self-assessment.

Asking students about under what circumstances they think self and/or peer assessment should be used, some interesting answers are listed:

- There must be a proper rubric to be used as an assessment guide.
- If self-assessment is used, everyone would be more engaged and active in classroom sessions.
- It will be interesting if the teacher reviews the marks of self and peer assessment.
- Inter-personal relationships can be an issue in peer assessment. The classroom mood must be good and relaxed.
- In self-evaluation we can be aware, and learn, from our own mistakes. In peer assessment we can learn from the work done by other students.
- It would be good for students with a well-measured self-criticism. The problem can arise in students who undervalue themselves, and vice versa, students who are more narcissistic who feel they deserve a higher grade than they should be.

Summarizing, students consider themselves as 'fair players' concerning self and peer assessment. With little instruction, they are fully aware about the learning possibilities of this kind of assessment strategy. To ensure they will be confident in this assessment, special care must be taken to ensure personal relationships are not being considered in the assessment. When asking them for their opinion about self and peer assessment, the answers that have been obtained tend to be more mature than expected.

5 Analysis of assessment data

In this section we are going to analyse if students' and teachers' opinion about self and peer assessment are correlated with the data obtained from courses using these types of assessment. Of all the courses presented in Section 2.1, a couple of examples is going to be presented together with some general thoughts.

The way in which self-assessment is addressed is different depending on the course. For first year students, it is necessary to be more directive in the way the instructions are provided to the students. In the case of the Basic Electronics (first year) course, the self-assessment is weighted with a 5% in the final mark. Students are asked to prepare a justified report and a proposed mark, based on the learning goals of the course structured in two questions:

- What skills have I developed by taking this course?
- What are the benefits of having taken this course?

The difference between the self-assessment mark and the final mark (0-10 scale) is displayed for about 750 students between 2011-12 and 2020-21 academic years, together with the average of this difference per year is presented in Figure 6.

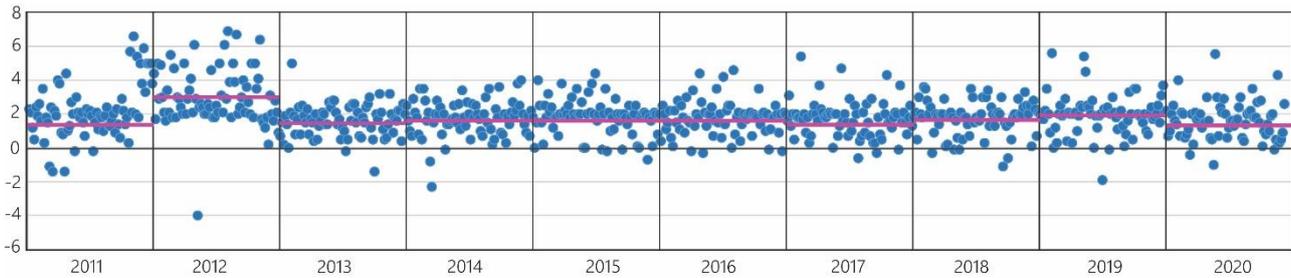


Figure 6. Numeric difference between self-assessment and final mark of a first year engineering course. Pink bars indicate the average difference per year.

Even this data come from first year students, which are supposed to be less mature, there is clear consistency in the results. There is a quite stable offset of two points between the marks. The person responsible of the course is quite satisfied with the self-assessment reports and marks. His opinion of this two points' difference is a mix between a slight over-rating and an evaluation scheme that can be improved.

Some results of peer assessment can be obtained from the 3rd year Video engineering course. In this course, peer assessment is used as the main tool in the process of evaluation of projects. Figure 7 presents the difference between peer assessments and teacher marks for the 21 working groups in a given year. The data displayed corresponds with the average of all the marks assigned to each one of the working teams related with one of the projects developed.

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 is there a high degree of correlation but in half of the cases, students are marking their peers with a more severe criterion. Although Figure 7 depicts data from one year, the tendency we have obtained is similar in almost every year. Little exceptions have been found corresponding with years with reduced number of students (and, logically reduced number of working teams).

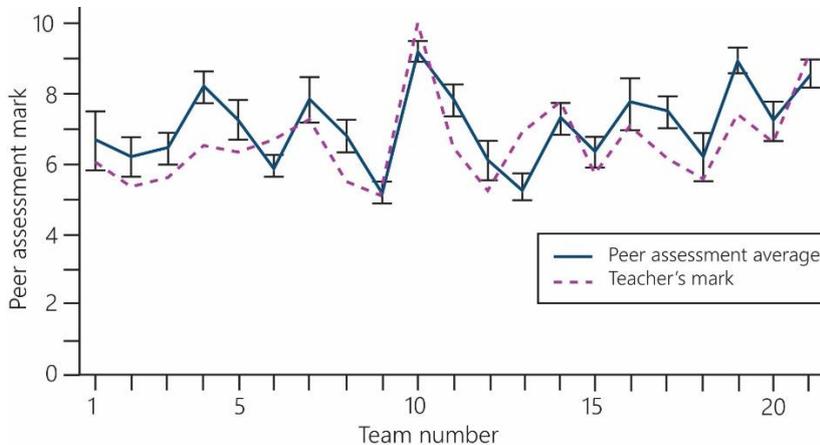


Figure 7. Comparison between peer assessment and teacher's marks from a 3rd year engineering course.

The last behaviour to explore is the relationship between the self-perception (self-assessment mark) and the marks assigned to the rest of the teams (peer assessment mark). Figure 8 represents the dispersion comparing the difference between self-assessment mark with the average of the received peer assessment marks ($SA-PA_r$) with the difference between assigned peer assessment and the average mark of all the peer assessments (PA_a-PA_{avg}) for the same 21 teams of Figure 7. The data have been normalized in a ± 1 range.

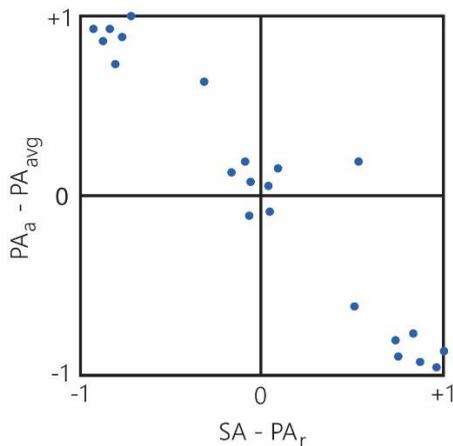


Figure 8. Relationship between self-perception and assigned peer assessment from a 3rd year engineering course.

Figure 8 shows a clear trend. The groups with the highest level of self-demand ($SA - PA_r < 0$) have a tendency to rate the rest of the groups with higher grades ($PA_a - PA_{avg} > 0$). Likewise, groups that rate themselves with higher grades ($SA - PA_r > 0$) tend to be more demanding when rating the rest of the teams ($PA_a - PA_{avg} < 0$). The global reference provided by the implementation of peer assessment generates a consistent marking reference that it used in the self-assessment when both strategies are used simultaneously.

6 Conclusion

Learning outcomes associated to self and peer assessment have been widely stated in bibliography. However, it is easy to find teachers who are reluctant to the use of these assessment methods. Besides, a considerable number of students don't know the difference between formative and summative assessment. Some effort must be done in training on assessment strategies addressed to both teachers and students to help them be confident in 'non-traditional' assessment methods.

According to teachers' perspective, the main risks associated to self and peer assessment are the lack of reliability, not being confident in student criteria and how to justify evaluation results to other colleagues or external examiner.

One of the most cited fears by students is related with the risk of being assessed by peers biased by personal relationships. Apart from this, students are quite receptive to the use of self and peer assessment showing a clear idea (or intuition) about their benefits.

Acceptable levels of correlation between self and teacher's assessment has been supported by the data analysed. A quite consistent behaviour has been observed. Using peer assessment to evaluate projects, with all working groups solving the same project, has delivered high levels of correlation with teachers' opinion. If self-assessment is used in the same framework, the reference of peers' work becomes a solid basement for the self-assessment.

7 Acknowledgment

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Project Based Learning Approach in the Heat Transfer Course for Undergraduate Students

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Abstract

Computer engineering courses often require knowledge from other fields, such as numerical methods and heat transfer. It is challenging to motivate students and show them how the contents presented in these units are connected to the core of their course. This paper presents a project based learning experience for third year undergraduate students of computer engineering at Insper Instituto de Ensino e Pesquisa. The students are required to work in teams to design a cooling system to a processor in a free version of the finite element software LISA. The theme of the project builds the bridge between heat transfer and computer engineering and the tool shows the importance of numerical methods in engineering. Teams are free to select any processor available in the market and choose fictitious parts, such as fans and fins, from a list provided by the instructor. Each item in the list is associated with a price, so they must propose and simulate numerous designs to optimize their final cost. Their designs are initially based on observation of the cooling systems available in computers and smartphones and then improved by their heat transfer knowledge. Students present their solutions to sell their designs in the end of the project. This experience could be adapted into a contest for the lowest cost if a single processor was provided to all groups. A contest can motivate the students, but may also worry them, while a free choice has been successful in making them active and keeping a light environment. This experience can be accomplished remotely without expensive software and create a bond between heat transfer, numerical methods and computer engineering.

Keywords: Project Based Learning; Heat Transfer; Numerical Methods; Engineering project.

1 Introduction

Many engineering courses have heat transfer and numerical methods units in their programme, but the importance of those units may not be clear to the students. For example, a computer or electrical engineering undergraduate may not see a straight connection between heat transfer and the core of their engineering courses. Also, the role of the engineer has changed lately and companies have been requiring their specialists to have a broader understanding of the projects (Santos, Ayres, & Miranda, 2018), not only regarding technical aspects but also about entrepreneurship, design thinking (Goldberg & Somerville, 2014) and soft skills (Kumar & Hsiao, 2007). Therefore, it is necessary to motivate engineering students to acquire knowledge from other fields.

Active learning (Christie & Graaf, 2017) strategies and project based learning (Kokotsaki, Menzies, & Wiggins, 2016) approaches have been widely used in engineering courses, especially to develop interdisciplinary tasks. The laboratory was transformed in an escape room game by (de la Flor, Calles, Espada, & Rodríguez, 2020), where chemical engineering students needed to answer heat transfer questions correctly to win. A sequence of tasks under the PBL methodology was designed by (Montero & González, 2009) to first year electronic engineering students, but their objectives did not include numerical methods. A PBL approach was suggested by (Zhuge & Mills, 2009) to motivate students to learn basic concepts of the finite element method. They focused on structural analysis and used a commercial software to develop their models. In this work, numerical methods and heat transfer are combined in a 1 week project under the PBL approach. Each team of students must select an existent processor, design a cooler by assembling parts from a list and use a finite element commercial software to simulate its performance.

This project was designed for third year computer engineering students, but the methodology can be applied to most engineering modules. Either as an introductory activity in courses that have heat transfer as a core unit (mechanical engineering, for example) or as a complementary assignment to other engineering curriculums.

This project does not require prior knowledge related to the finite element method or any commercial software, but students will have to analyse and discuss their results, therefore a reference containing such information has to be indicated.

2 Objectives and expectations

In this project, teams are free to select any processor and design the heat fins as they prefer. We expect this to enhance the engagement of the students in the project because they can choose a processor they have in their computers, mobile phones, videogame consoles, etc. Also, the solution space on heat fin designs is too wide, therefore teams that discuss more and work creatively tend to perform better in such an open-ended situation.

Many undergraduate engineering projects focus too much on the technical aspects and leave the cost out of the study. By including this aspect, we expect the students begin to consider the price of the components in their thoughts more often.

The main learning objectives of this project are:

- Research technical data of processor units
- Apply heat transfer knowledge (conduction and convection) in processor cooling systems
- Discuss and create potential configurations of coolers
- Solve heat transfer analyses in a finite element analysis software
- Understand concepts behind numerical solutions (finite element method)
- Eliminate and/or improve inefficient cooling systems based on heat transfer knowledge and simulation outputs
- Find a configuration that satisfies the maximum operation temperature of the processor
- Design a brochure with fundamental information on the final product

We expect this project to introduce the theoretical studies on conduction, convection and numerical methods. Depending on the course, it should be followed by a deeper study of the heat transfer governing equations and numerical methods algorithms.

3 Description of the activity

This project can be divided in four main stages: selecting a processor, assembling a cooling system from fictitious parts available in the store, using a finite element software to improve the system and presenting a brochure with the optimized configuration. The due date is within a week from publication of the assignment text.

3.1 Selecting a processor

Students are free to select any real processor, but their main technical data will be needed in the next stages of the project, therefore we encourage them to pick a processing unit whose specifications can be easily found. Most teams select AMD or Intel cores due to their popularity and availability of information, but a few students have explored smartphone processors and graphics processing units (GPU).

3.2 Assembling a cooling system

Instructors provide a list of fictitious parts and their respective cost (Table 1). Students can assemble their coolers by selecting a fan (if any), build a dissipator base to place heatfins on and assign one or more materials to their systems.

Table 1. Fictitious hardware store. Material properties retrieved from (Incropera, Dewitt, Bergman, & Lavine, 2007).

Price (\$)	Hardware
30	Breeze fan ($h=30\text{W/m}^2\text{K}$)
60	Gust fan ($h=50\text{W/m}^2\text{K}$)
120	Cyclone fan ($h=80\text{W/m}^2\text{K}$)
5/heatfin	Heatfin manufacturing
$0.0005/\text{mm}^3$	Aluminum ($k=237\text{W/mK}$)
$0.02/\text{mm}^3$	Copper ($k=401\text{W/mK}$)

3.3 Using a finite element software

To quantify the performance of their coolers, students must model the assemblies in a finite element software. They are encouraged to use the free version of the LISA FEA software (Figure 1) (Sonnenhof Holdings, 2011), as it is an easy to learn tool and has enough resources to fulfil the objectives of this project. A video tutorial was provided by the instructors.

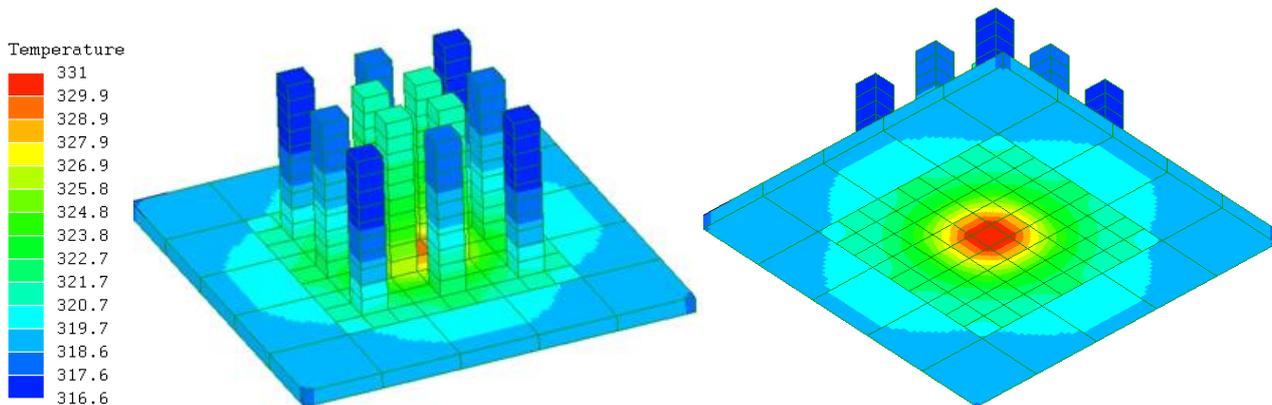


Figure 1. Example of a heat transfer analysis in the LISA FEA software of a cooling system. Temperatures in K.

There is a maximum limit of nodes in the free version of the software, which can be seen as an opportunity to create a sense of waste of resources. This limitation helps the students learn to refine their meshes around critical areas only, and not on the whole model.

The processor core is modelled as a heat flow rate on the bottom of the dissipator. Its Thermal Design Power (TDP) and dimensions depend on which processor was chosen by the team. The design of the dissipator base and fins are free, but the materials must be listed in the store. The exposed portion of the base is subject to free convection, while the fins are subject to forced convection, whose coefficient h depends on the fan the team has selected from the list. They can also decide to not use any fan (which is mandatory for mobile processors, for example), in this case, fins are also subject to free convection. The main technical objective is to keep the highest temperature below the maximum operating temperature of the processor while minimizing the total cost of the system. Therefore, a solid discussion and a few trial-and-error iterations are required to obtain an improved solution.

3.4 Presenting a brochure

After analysing potential cooling systems, deciding on a better configuration and optimizing it, each team must create a brochure and pitch their cooler to the teachers. The brochure has to contain the processor's name, TDP and junction temperature, simulation parameters and outputs, final cost and all relevant information about the cooling system.

3.5 Assessment rubrics

To make the grading process more objective and accurate, a few topics are assessed and the grades are calculated under the rubrics **Invalid source specified**, presented in Table 2. The main topics to be assessed are:

1. Brochure: showed technical data of the selected processor unit
2. Brochure: showed a finite element analysis (graph/figure) of their design
3. Brochure: satisfied the maximum operation temperature of the processor
4. Pitch: mentioned previous configurations of coolers
5. Pitch: discussed heat transfer processes and their importance on the design

Table 2. Assessment rubrics.

Incomplete (0%)	Developing (25%)	Essential (50%)	Proficient (75%)	Distinction (100%)
Items 1 or 2 are incomplete.	Cleared only items 1 and 2.	Cleared only items 1, 2 and 3.	Cleared only items 1, 2, 3 and 4.	Cleared all items.

4 Student submissions

This section contains two examples of student submissions we found to be interesting. In the first example (Figure 1), all mandatory information is present in the brochure and the team managed to keep the highest temperature within the limit specified by the manufacturer. Even though their design could have been further optimized, e.g. removing cold spots from the external fins to save material, it is safe to state that the requirements of the assignment have been attended. Contrarily, the second example (Figure 2) lacks the final cost of the system, also their fins are poorly distributed as the hottest region of the dissipator does not have a fin and the fins on the corners are cold. This kind of submission suggests the team knows how to operate the software and understood the main objectives, but their learning experience would benefit from a richer discussion and more trials.

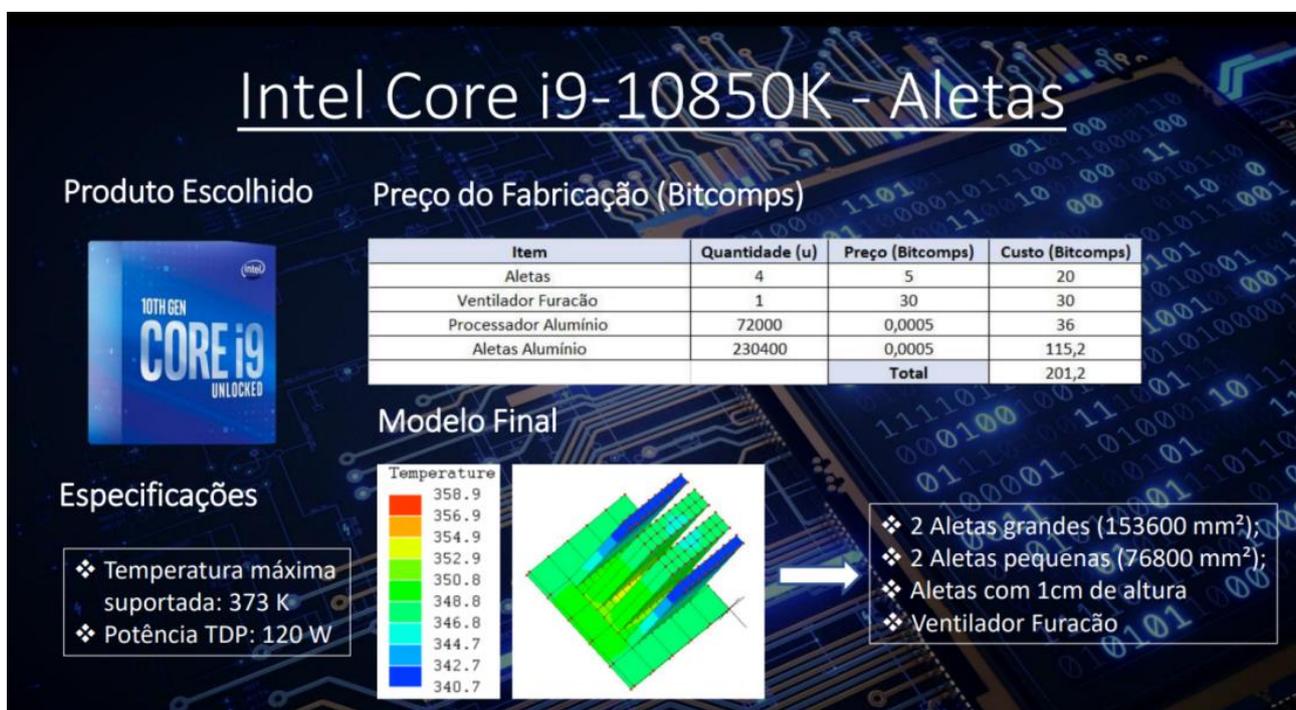


Figure 2. Student submission 1.

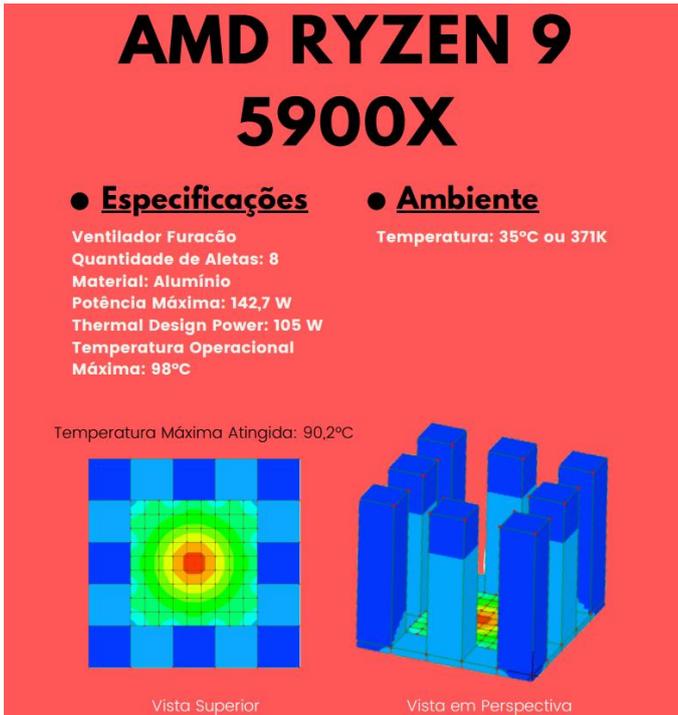


Figure 3. Student submission 2.

5 Performance of the students

Only 50% of the teams presented a brochure in the end, the other groups organized the results in different formats. The proposal of using a brochure to advertise their coolers must be reinforced in a future iteration of this project. Additionally, during the group discussions, a few students wanted to explore different processor units but did not manage to convince their partners. If the teams had been divided according to processor preference, maybe more diversity of coolers would have appeared. Only one team chose a mobile Snapdragon processor while all other groups selected regular CPU from Intel or AMD.

However, all teams developed cooling systems that satisfied the maximum temperature allowed by the manufacturer, which indicates they understood the basic objective of the project and all of them obtained at least a 5/10 grade. Around 30% of the teams truly dived in the problem, presented fine results and obtained a maximum 10/10 grade.

6 Teachers' perception

The first designs of the students were mostly based on observation of coolers and slight improves on the tutorial we provided. But many groups managed to discuss and provide better results based on heat transfer knowledge. The activity can run remotely or in person as long as the teachers can enter the group discussions to hear and eventually steer the conversation into fruitful topics. Also, each team has access to at least one computer. We found it may become too demanding for a single teacher to interact at a personal level with the teams if there are more than 20 students in the class, it is ideal to have at least two instructors to follow the group talks in that case.

If all teams were forced to use the same processor, this project could be transformed in a contest where the team with the lowest price cooler (that satisfies the maximum temperature) would win. The competition would favour the optimization step and could extrinsically motivate a few groups, therefore it is worthy being considered, but we felt most of the students were already intrinsically motivated by the free choice of processor. The non-competitive atmosphere foments cooperation between groups, which enhances the learning

experience. Additionally, in a scenario where all groups have the same processor, plagiarism would become a concern for the teachers and among teams.

7 Conclusion

An open-ended PBL activity on heat transfer and numerical methods has been presented. The experience was executed on a computer engineering class at Insper Instituto de Ensino e Pesquisa, but any undergraduate engineering course can run this project. Students worked in teams to develop a processor cooler using parts from a fictitious store and a finite element software. The final handout was a brochure containing information about their designs, two student submissions were presented as examples. The first example may not be optimal, but it surely had been improved to a certain extent and attends the expectations. The second example indicates the team could have discussed better and tried more configurations to show a more efficient cooler. A table for assessment rubrics is presented to increase the accuracy and objectivity of the grading process. Future steps involve reinforcing to the students the value of the brochure format, applying the project methodology on students from other engineering modules and running a questionnaire to accurately assess the students' perception. From personal interaction with the teams, the project was well accepted by most of the students, who understood the importance of heat transfer concepts, teamwork and numerical methods to engineers of all fields.

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Do Brazilian Engineering Professors Do Engineering Education Research in Active Learning? A Case Study

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Abstract

While in countries like Brazil, the concern is still the training of instructors in the use of active learning strategies and methods, in countries such as the United States, Denmark, Sweden, Australia, for at least two decades, research has been placed at the service of teaching and teacher professional development and projects are developed so that research in Engineering Education is carried out with greater rigor. In this context, this research work aims to evaluate a set of interventions presented at the 43rd edition of the Brazilian Congress in Engineering Education (COBENGE), from the year 2015, because of the theme of the event: "Active Learning: Collaborative Engineers for a Competitive World. Thirty-six 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 an effective teaching (ET), a scholarly teaching (ST), a scholarship of teaching and learning (SoTL) or an engineering education research (EER) work. Our results show that from the 36 papers analyzed 25 are ET, 1 is ST, 2 are SoTL, 4 are EER works, and 4 could not be characterized in any of the levels. We present and discuss the approach built for the analysis performed based on the characteristics pointed out by the literature for ET, ST, SoTL and EER. It is worth pointing out that ST and SoTL are concepts little known to the Brazilian EE community. This research work is a starting point to evaluate the state of engineering education research in Active Learning in Brazil.

Keywords: Active Learning; Effective Teaching; Scholarly Teaching; Scholarship of Teaching and Learning; Engineering Education Research.

1 Introduction

According to de Graaff and Christensen (2004), active learning (AL) and Engineering Education (EE) are a perfect match, and thus engineering professors can be expected to employ active learning strategies and methods in their classes and courses. After all, the engineer must be educated to design and create solutions to practical real-world problems. Over the past two decades, research has shown that students prefer classes with active learning strategies and methods over traditional classes and that the adoption of AL instructional practices in STEM courses results in improvements in student learning, contributes to decrease dropout rates and reduce the performance gap between different student populations (McConnell et al., 2017; Freeman et al., 2014). In these research works, student performance was also evaluated and it was found that many AL strategies are comparable to traditional classes in promoting content mastery, but superior to promoting student skills and competence development (Freeman et al., 2014; Kay & MacDonald, 2016).

Unfortunately, even today, in many engineering schools in Brazil, the dominant pedagogy remains "chalk and talk" and curricula with a few project courses and laboratory practices, which are not enough to develop the skills desired by the world of work. In Brazil, both the possibilities and the challenges related to EE are debated by the participants of the Brazilian Congress in Engineering Education (COBENGE), which is considered the most important forum for reflection on EE in Brazil. The event is annually promoted by the Brazilian Association of Engineering Education (ABENGE), with the objective of bringing together schools and instructors to, together with government agencies and other entities interested in EE, share experiences, promote debates and propose strategies to train professionals increasingly more qualified to meet the country's needs.

Considering the obvious need for stronger actions regarding the creation of engineering programs that prepare engineers in tune with the problems of the 21st century, the Active Learning Working Group in

Engineering Education (GTAAEE¹) was created during COBENGE 2014. The GTAAEE has as main objectives: to disseminate the knowledge generated in active learning in engineering education (ALEE); to promote the creation of a research network in ALEE in Brazil; to foster the formalization of research groups in the area, in the most diverse engineering schools; and to promote the training of teachers to design AL environments (GTAAEE, 2022).

In 2019, seeking to update data on the use of AL strategies and methods in Brazil, previously surveyed by Oliveira, Pinto & Santos (2017), some GTAAEE researchers presented a study, from a systematic mapping, of articles published in the proceedings of COBENGE on AL strategies and methods from 2007 to 2019 (Pinto et al., 2019). The results obtained have shown an exponential growth in the number of publications of ALEE-related articles in COBENGE. This reveals the increasingly intense search by instructors and researchers for a teaching process focused on the development of skills and competencies.

In countries such as the United States, Denmark, Sweden, Australia, EE and research in EE are very advanced. For example, while in countries like Brazil, the concern is still the training of instructors in the use of AL strategies and methods, in the United States and in the aforementioned countries, for at least two decades, research has been placed at the service of teaching and teacher professional development and projects are developed so that research in EE is carried out with greater rigor (Shuman, & Besterfield-Sacre, 2019; Borrego & Bernhard, 2011; Streveler, Borrego & Smith, 2007).

Also, in 2019, the new National Curriculum Guidelines (BRASIL, 2019) for Engineering programs in Brazil were published, and it is believed that their implementation is a unique opportunity for more programs to have their curricula designed for competency-based training once and for all, which inevitably demands the incorporation of AL strategies and methods so that these curricula are, in fact, executed in their essence.

Allied to this, one must consider that, researching and reflecting on what one does in the classroom and then sharing it with peers is not a common practice among engineering professors. One of the reasons why this kind of research is often underestimated is that EE is not considered a research area in Brazil. Although the professors are teachers, they are not researchers in teaching and learning. For the most part, they are not trained in pedagogical methods, or self-identified with the professional community dedicated to research in education. Although the engineering professor may wish to engage in educational research, more often than not, he or she gets frustrated and gives up because they have no idea where to start. This becomes clear in the evaluation process of the papers at COBENGE. The great majority of the papers presented at the event do not present well-defined educational objectives, nor research objectives, and some do not even mention the term "engineering education".

In this context, and based on the objectives of GTAAEE, researchers of the group started a research, whose main objective was beyond the survey of the number of papers related to the application of AL strategies and methods, to determine the nature of the pedagogical interventions reported in the papers presented at COBENGE and to determine how much of these papers are research papers, minimally rigorous, in EE. Thus, this research paper aims to evaluate a set of interventions presented at the 43rd edition of COBENGE, held in the year 2015, due to the event's theme: "Active Learning: Collaborative Engineers for a Competitive World", a suitable starting point to evaluate the state of engineering education research in Active Learning in Brazil. Thirty-six papers presented at this edition of COBENGE, and which were related to AL, were analyzed to determine whether they are papers that address interventions such as effective teaching (ET), scholarly teaching (ST), scholarship of teaching and learning (SoTL), or research in engineering education (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 ST, SoTL and EER. In other words, we can consider that ET, ST and SoTL are progressive levels of maturity of EER.

The following topics are presented in this article: a brief theoretical framework for ET, ST, SoTL and EER, the research methodology employed, the results and some final considerations.

¹ in this paper, the acronym used will be the acronym in Portuguese.

2 Theoretical Framework

In this section, the goal is to distinguish reports of pedagogical experiences from research associated with pedagogical interventions and from more complex research in EE. To this end, a brief description of the EER levels named ET, ST, SoTL will be given, and the basic principles of more complex EER will be presented.

2.1 ET (Effective Teaching)

An Effective Teaching intervention requires the use of good content and good teaching methods and tends to promote desirable learning outcomes. Kipper & Rütman (2012) point out models and strategies for Effective teaching in order to provide successful learning and the development of critical thinking in engineering students. They agree with Eggen and Kauchak (2006) that mastery of four types of knowledge by instructors is essential: (i) knowledge of content - what to teach; (ii) pedagogical content knowledge - how to teach a certain content; (iii) general pedagogical knowledge – understanding of general principles of instruction and classroom management; and (iv) knowledge of learners and learning – instructor’s ability to adapt their instruction based on what learners already know. Thus, when the intent is to characterize an Effective Teaching intervention, these elements should be identified in the teaching practice, through an assessment of student satisfaction, peer observation appraisal, self-reflection, among others.

2.2 ST (Scholarly Teaching)

A Scholarly Teaching intervention is nothing more than academic teaching. It implies the adoption of an academic approach to teaching, just as it is adopted for other areas of knowledge. It requires research and includes reflection. The instructor needs to have expertise in teaching and learning, to experiment with new pedagogical strategies and methods, to study and apply the literature on teaching and learning in the courses, to reflect on his/her teaching. According to Richlin (2001), "Scholarly teachers are those who consult the literature, select and apply appropriate information to guide the teaching-learning experience, conduct systematic observations, analyze the outcomes, and obtain peer evaluation of their classroom performance".

2.3 SoTL (Scholarship of Teaching and Learning)

A Scholarship of Teaching and Learning intervention involves high level academic teaching and learning. It addresses university teaching and learning by investigating student learning in the classroom. According to Rütman & Saar (2017):

In general, SoTL includes rigorous, systematic, and evidence-based study of student learning; the understanding and improvement of student learning and/or teaching practice; commitment to disciplinary and/or interdisciplinary peer review and appropriate public dissemination; impact beyond a single course, program, or institution – advancing the field of teaching and learning to build collective knowledge and ongoing improvement. (Rütman & Saar, 2017, p.214)

It emphasizes the identification and definition of a problem and demands systematic collection of evidence that will be the results from which conclusions will be drawn (Dewar, Bennet & Fisher, 2018). The instructor needs to have knowledge of the disciplinary content, of effective pedagogical practices, and of discipline-specific pedagogical practices. According to Streveler, Borrego & Smith (2007), the involvement in SoTL usually begins with faculty's interest in how their own students are learning in their classrooms, and the main purpose of SoTL is to improve learning by improving teaching. " The results of a Scholarship of Teaching and Learning intervention should add knowledge to the literature on teaching and learning and contribute to the scientific productivity of the faculty.

2.4 EER (Engineering Education Research)

EER goes beyond the classroom and student learning and consists of the development of more rigorous studies related to EE (Streveler, Borrego & Smith, 2007). The ultimate goal of EE is, among several, to influence classroom practice and policies for conducting engineering programs from its findings. In EER, the researcher focuses on the "why" and the "how" of the educational phenomena involved in EE. The researcher identifies relevant, meaningful research questions; reviews the literature, links to appropriate theory, uses appropriate

research methods aligned with the research question, interprets the data, disseminates the results in a generalized way. In general, EER demands a set of methods and processes that can be seen as different from the usual research in specific engineering disciplines. Borrego (2007, p. 99) claims that "research [in EER] is fundamentally different from engineering research". This turns out to be a hindrance to the development of EER, since most engineering professors lack familiarity with literature in the field of education and with research methodologies suitable for educational studies (Froyd & Lohmann, 2014).

Having presented the main characteristics related to ET, ST, SoTL and EER, the next section will present 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 2015, regarding the classification of these papers as being pedagogical interventions, such as ET, ST, SoTL, or research in EE. 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 36 studies involving AL strategies and methods published in the annals of COBENGE 2015 and analyzed in this work, was carried out by Pinto et al. (2020) with the main objective of, as mentioned before, verifying the growth of AL in EE 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 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 the classification into ET, ST, SoTL or EER, the characteristics described in sections 2.1, 2.2, 2.3 and 2.4 were taken into consideration. The researchers randomly divided the 36 papers into two groups of 18 papers. Each analyzed 18 papers. In case of doubt, the work was read by the other researcher, and this second reading was followed by a discussion between the two researchers. The characteristics described in sections 2.1, 2.2, 2.3, and 2.4 were sought in each of the papers. When found in the papers, these characteristics were highlighted and noted.

In the next section, the results obtained through the described procedures are presented and discussed.

4 Results and Discussion

Table 1 shows the number of papers classified in each of the levels, namely ET, ST, SoTL or EER.

Table 1. Classification of papers in ET, ST, SoTL and EER levels.

ET	ST	SoTL	EER	Other
25	1	2	4	4

The general analysis of the classification shows an imbalance between the quantity of ET papers, which include experience reports, 69% of the total number of papers, and scientific research papers, which include the ST, SoTL and EER levels, and represent 19% of the total number of papers analyzed. In addition, 11% of the papers do not fall into any of the levels. The most relevant results for each level are presented and discussed below.

4.1 ET

COBENGE accepts two types of papers, "experience report" and "scientific research", however, there are no clear criteria for what is an "experience report". Of the 25 papers initially classified as ET, 72% focused on technical issues of the project/experiment developed, while 28% focused on the methods and strategies of ET. In both cases, there were papers with: evidence of student learning gains, mostly results of grades from evaluative activities, such as traditional tests; results from satisfaction surveys; and statements from the authors

that the learning was effective, although without verifiable data. These are all papers that claim to present an innovation in the classroom. However, as pointed out by Wankat, Felder, Smith, & Oreovicz (2002, p. 217), the evaluation of innovation is typically something like "We (the teachers) tried it and liked it, as did most of the students". Based on these characteristics, we defined the experience reports (ER) intervention as: descriptions of methods applied in the classroom and/or development of experiments or prototypes to support teaching. In general, the ER interventions do not present a consistent theoretical review of the AL strategies and methods nor do they provide criteria, data, or evidence of learning gains. In this sense, in this research, it was decided to formalize the ER level for the papers presenting these characteristics. From the 25 papers initially classified as ET, 18 papers were reclassified as ER, which means 50% of all 36 AL papers.

Among the six works classified as ET, we highlight the work of Guimarães et al. (2015), in which the authors describe an activity developed and coordinated by students of a group from the Tutorial Education Program, under faculty mentoring, directed to freshmen and inserted in the "Introduction to Electrical Engineering" course. From instructions and materials prepared by the students who organized the activity, teams assembled line following robots and, in the end, participated in a competition. It is worth mentioning that there are learning gains for all involved, students who are the organizers and freshmen, and that competitions of this type generate engagement and emotional involvement, contributing to the consolidation of new knowledge. The authors explain that the activity involves technical knowledge, mainly related to electronics, as well as attitudes such as proactivity, flexibility, tolerance to uncertainty, and skills such as teamwork, written and oral communication, planning, management and leadership. The results include team and participants' evaluation of the activity and the project, reflection on the technical and non-technical learning gains, and the paper also mentions agreement with the competencies expected and based on the National Curriculum Guidelines² and on ASIBEI³. The instrument mentioned for data collection is the questionnaire.

Analyzing in more detail the work of Guimarães et al. (2015), one realizes that experiments, team brainstorming, reflections, and non-formalized observations were carried out. It is possible to identify characteristics of action research and the interrelation between teaching, research, and extension. It is observed that there are numerous instruments that can be used to obtain evidence of effective teaching in addition to those already mentioned: interviews and focus groups; content analysis; experiments; case studies; multi-method studies and hybrid methods.

The paper highlights the competences exercised in each phase of the proposed activity, such as planning, elaboration, testing or execution, and this helps in the definition of learning indicators that can be used to analyze student performance and generate evidence for evaluating the results of a proposal. A review of the literature including similar experiences, greater care with methodological procedures regarding the strategies and methods of AL and the methods of data collection, as well as the evaluation of student performance, would elevate the work to the ST level.

4.2 ST

In the ST level, a single paper was identified (Spricigo, 2015), which presents the results of the application of the PBL method in a technical feasibility study of an industrial enterprise in a class of 17 students in a course of the Food Engineering program, replacing the traditional lectures previously held. The author presents the method adopted, in which an open problem divided into two parts was chosen. The methodology developed involved the presentation of the results and a debate with the class about the solution found by each team. To evaluate the students' motivation the Situational Motivation Scale (SIMS) was used. For the evaluation of learning gains, the grades of an individual written test on a problem-situation similar to the theme of the applied PBL were considered. Rubrics were used to correct the test. Results obtained with the use of the SIMS scale indicated a high level of intrinsic motivation and a low level of demotivation in the class during the PBL.

² National Curricular Guidelines for Engineering Courses, Resolution CNE/CES 11, of March 11, 2002. The New Curricular Guidelines, of April 24, 2019, are currently in effect.

³ Declaration of Valparaíso on Generic Competences of the Iberoamerican Engineer

However, extrinsic motivation, which indicates the execution of activities to obtain a reward, was representative. In the individual test results, 90% of the students met all rubrics. The author makes reflections based on the qualitative results of the teams and mentions gains in complexity in the issues discussed and in the role of the professor as mediator.

The main characteristics identified in the analyzed work are: adoption of academic approach to teaching; use of hybrid methods; experimentation with new techniques; application of literature on teaching and learning in the course; reflection on teaching; evidence-based study of student learning; analysis of understanding and improvement of learning; impact on a single course.

Although Spricigo's (2015) work presents the characteristics of an ST, the application of the PBL method was not developed considering all the stages of the method, nor the evaluative instruments usually used when applying PBL, for example, peer and self-assessment. Recommendations for a paper like Spricigo's (2015) to be classified as a SoTL also involve sharing experiences and reflections on the results with professors from other courses and programs; for it to be classified as an EER, it would need to broaden the scope of application of AL methods and strategies, include real problems involving companies and/or professionals in the field, and/or promote continuous improvement of the results.

4.3 SoTL

In the SoTL level, the works of Chinaglia & Santos (2015) and Gomes, Lima & Bianchini (2015) were identified. In the first, the authors present quantitative results on the introduction of AL strategies for large physics classes. The research involves an experimental group of 247 students who participated in the new teaching proposal, a control group with 124 students submitted to the traditional teaching method, and 3 instructors responsible for each group. The new methodological proposal includes lecture, demonstrative simulation, conceptual test, and group work to solve problems. The traditional method consists of lecture and exercise solving by the instructor. The authors used the mechanics baseline test, known worldwide as the "Force Concept Inventory" (Hestenes, Wells, & Swackhamer, 1992) to assess the prior knowledge of all students and found a leveling of the classes. The effectiveness of the developed methodology is verified by comparing the average scores of the students' performance on 3 tests and also their attendance in class. Besides the improvement in the average grades, the experimental class presented a lower rate of absences. After this experience, the proposal started to be applied in 100% of the physics courses, involving all the physics instructors of the institution. Also in this paper, despite the good results achieved, a certain lack of knowledge by the authors about the AL strategies is noted. In this particular context, when using conceptual tests in the development of the classes, the authors do not mention the Peer Instruction strategy, famous for its excellent results in learning gains in physics courses, and whose central point is the conceptual test conceived by Mazur (1997).

In the second paper, Gomes, Lima & Bianchini (2015) investigate the learning gains of 25 freshmen of an engineering program, by means of an intervention carried out with the Jigsaw method of cooperative learning, as part of a doctoral research of the Graduate Studies Program in Mathematics Education of São Paulo's Pontifical Catholic University (PUC/SP). The chosen subject was the study of the line in two- and three-dimensional spaces. Five study themes were proposed, a final question and an individual evaluation question. They used as methods of data collection, observations and interviews. All five groups did well in the development of the activities. The authors infer that "the Jigsaw method of cooperative learning can allow students to move through other styles of mathematical thinking different from their preferred ones". It is observed in this paper the authors' deep knowledge of the Jigsaw method (Aronson, & Patnoe, 2010). This characteristic of the article may be associated with the fact that the research work is linked to the development of a doctoral thesis.

Common features of the papers are: good description of methodological procedures, including data collection methods; analysis of results; extrapolation from the classroom; systematic evidence-based study of student learning; the understanding and improvement of learning; engagement with disciplinary colleagues; impact on multiple courses.

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. In Brazil, teacher training in engineering programs is still incipient, and most of the time, actions related to improving teaching are generally the teacher's own initiative or rare teacher training sessions.

4.4 EER

In the EER level, four papers were identified, which in common present theoretical review, describe the methodological procedures, including data collection methods; analyze the results from the data and demonstrate that the objectives were met. They certainly go beyond the classroom, however, a feature that draws attention is the fact that all of them address the Project-based learning (PjBL) method. Three papers are related to the organization of curricula of engineering programs, three are from Brazil and also three had explicit cooperation with the University of Minho (UMinho), not necessarily the same papers.

It is worth highlighting the work of Schlichting & Heinig (2015), from the Graduate Program in Education at the Regional University of Blumenau. The authors discuss the implications of AL regarding the uses of orality, reading and writing in the professional daily life in engineering. This is a qualitative research that involves discourse analysis from interviews conducted with students from the 7th semester of the Integrated Master in Industrial Engineering and Management at UMinho. The research brings a contextualization of the scenario studied at this university from the perspective of PLE (Project-Led Education) and also about its relationship with the world of work. The authors present a consistent theoretical framework as a basis for the analysis and discussion of the results. The methodological procedure is presented in a diluted form, throughout the text as the students' statements are interpreted from their experiences in the PLE and their first professional experiences. The authors attest to the need of inserting the student in realistic interaction practices and the importance of a spiral curriculum, in such a way as to allow the student to move from general knowledge to specialized knowledge. It is interesting to note that the authors' conclusion refers to Bruner's discovery learning in which the learner is exposed to the same topic in different ways and levels of depth.

Another work of interest is that of Santos and Silva (2015), which presents the experience of the first contact with the project-based learning method from the perceptions of freshmen of the computer engineering program at the State University of Feira de Santana, in northeastern Brazil. A questionnaire answered by 14 participants brings the students' impressions. In the first part, questions about satisfaction are raised; in the second part, the skills developed; in the third part the infrastructure is evaluated, and in the last part the overall satisfaction with the method is raised. Although it has been classified as an EER, from the analysis of this work it can be seen that the authors could have mentioned similar applications in the theoretical review in order to compare the results found with those in the literature and thus be able to better evaluate the contribution. Also, the PBL model used was not well clarified.

5 Final Remarks

A reflection on such a large quantity of papers (50% of the total, classified as ER) that only describe practices or procedures without effectively demonstrating the gains in student learning implies a greater attention to the training of engineering professors for EE issues. In many papers, gaps are observed about several important aspects of AL strategies and methods, such as the stages of application, the evaluation of learning when applying such a strategy/method, among others. It is essential that the instructor knows the AL strategy and/or method that he/she will use in the design of the learning environments in order to be able to choose which one will help in the development of the intended learning outcomes. Only then, the instructor will be able to develop a good ET intervention.

The very small number of papers classified as ST and SoTL is closely related to the fact that most engineering schools in Brazil are not supported by faculty training programs. The results of a survey conducted by the ABENGE's Teacher Training Working Group (Battistini & Mattasoglio, 2020) on the training of engineering instructors confirm that in most higher education institutions in Brazil there is no space for the training of

engineering instructors. This data also supports the significant amount of ER papers found in this research. It is worth pointing out that ST and SoTL are concepts little known to the Brazilian EE community.

In relation to the EER papers, this research did not expect a significant number of papers in this level, after all, COBENGE is a national event, and EER papers, in general, are submitted for publication in specialized journals. However, it was expected early stage EER papers or clippings from a more robust research project. Here, it is worth presenting a result reported by Williams (2018), in which he highlighted that in the period from 2015 to 2018, Brazilian researchers submitted 14 papers to the Journal of Engineering Education in different EE subjects. Nine of these papers were rejected upon submission, five were revised, and none of them were accepted for publication. Unfortunately, this result presented by Williams points to a certain unpreparedness of Brazilian engineering professors for EE research.

Although the analysis carried out was in articles from 2015 and, therefore, can be considered a little outdated, what matters is that this research considers the theme Active Learning addressed in 2015 in COBENGE and is, as far as is known, a first step to analyze the state of the art of engineering education research in AL in Brazil.

This research work should be extended to evaluate a more significant number of COBENGE papers on AL strategies and methods, in principle, from 2015 to 2021. The results presented here point to the need of a discussion to be developed within the EE community in Brazil. As actions to improve the scenario presented here, the GTAAEE is working to organize its symposium which will address the theme "Scholarship of Teaching and Learning" and to create a tutorial for the planning of ET type interventions to assist in the submission of papers to COBENGE.

This paper will be finished with the following statement:

"Changing practice in engineering education so that faculty members apply findings in engineering education research, education research, and research in the learning sciences to their practice in engineering classrooms is a major challenge for engineering education practice and research (Jamieson & Lohmann, 2012)"

because this statement masterfully describes the great challenge that engineering education research in Brazil still has to face.

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Project-based learning applied to improve the performance of a family wine bottling unit

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Abstract

This article aims to show the effect of the application of concepts and principles of some operational excellence models, such as Lean Thinking and Shingo Model, in a family wine bottling unit. The project was carried out by a group of students in a project-based learning mode in the curricular unit "Lean Management and Organization" of the Master's degree in Systems Engineering at the University of Minho. The objective of the project is to implement actions and improve the overall performance of the wine bottling unit. The students started by making an analysis and diagnosis of the initial state of that production unit, identifying problems and opportunities for improvement, and introducing improvements that led to better performance. The main concepts and principles applied were value and waste identification; transport, movement and defect waste reduction; production in flow; and process focus. They managed to better balance the line, improve flow, reduce defects and increase productivity.

Keywords: Project Based Learning; Excellence Models; Lean Thinking.

1 Introduction

Over the years, there has been an increase in competitiveness in the world market, which together with the emergence of an increasingly demanding consumer, forced the evolution of production systems. Within that, the Lean philosophy emerged, which, according to Liker (1997) can be defined as an organizational model that seeks to eliminate waste and increase the agility and efficiency of the value stream. The concept of waste can be defined as any activity that uses resources, but doesn't produce any type of value and can be classified as: overproduction, when more is produced or before the moment is necessary; transport, when there is unnecessary movement of products/materials; inventory, when there is an excess of stored materials or products; waiting, when there is waste time waiting for the next step; overprocessing, when there is more work or higher quality than required by the customer; defects, when there is effort caused by defects, reworks and incorrect information; movement, when there is an unnecessary movement of people; human potential, when talent, skills and knowledge are wasted (Womack and Jones, 2003; Ohno, 1998).

To assist the identification of waste, Value Stream Mapping (VSM) (Rother & Shook, 1999)(Jones & Womack, 2002) can be used as a Lean tool to analyze and model production processes and, consequently, identify activities that add/don't add value (Busert & Fay, 2020). In addition, to monitor and evaluate the evolution of production, a set of performance indicators is used, aimed at eliminating waste, efficient use of resources and better control of the production process (Mourtzis et al., 2017).

The article describes the application of theoretical knowledge in a practical context with the aim of improving a family wine bottling line where production problems and operating difficulties were observed. The main objective is to understand how the application of Lean principles and techniques have an impact on a production line. In this way, it is intended to carry out an analysis of the production line and identify opportunities for improvement, collect data and information for analysis, propose and implement improvements and perform comparisons in the performance before and after the proposed changes.

In a first phase, in order to have a real perception of the production line, the group went to the farm, on a bottling day, and observed its operation. In addition, processing times were also accounted for in order to ensure the possibility of comparing performance indicators with the improvements implemented.

Then, to assess the state of the bottling line, a VSM was created, and some relevant performance indicators were established. In this way, it was possible to identify in which sections of the line improvements could be applied and/or problems that occurred during the analysis of the line could be solved. That said, a set of actions was developed and later implemented on the line, in order to account for new process performance indicators. After all the implementations, the new operation of the line was analyzed, and conclusions were drawn to understand the impact of lean techniques implemented in the bottling line.

The present article was developed by a group of students, within the scope of the curricular unit Management and Lean Organization, taught in the Master's degree in Systems Engineering at the University of Minho. The project was developed during the second semester of the academic year 2021/2022, and a group of three elements implemented the techniques taught in the curricular unit to this practical case. The curriculum of Master's degree in Systems Engineering aims to provide students a strong practical component on all the following curricular units: logistics, simulation, production management, supply chain optimization, systems analysis, similarity based systems, advanced database administration and exploration and two integrated projects. These two integrated projects are carried out over an entire semester and it's important to mention that they combine all the other units. The present project developed in the lean management and organization curricular unit fits in the Master's curriculum since there is a link between the course, the production and the industry so it is important to know the techniques learned in this unit. It also provides the practical component that becomes a valuable point for the students' learning, especially since it is a project-based learning.

At the beginning of the semester, the teacher explained the context of the project to the students, being that no specific theme was given to them, it was only necessary to apply all the knowledge that were being acquired throughout the unit to a practical case chosen by the group. The group decided to apply the project in a company context and the first task was to select it. After the selection, the group defined milestones to achieve a member responsible for having the most contact between the company and the group/teacher. Given the characteristics of the business, wine bottling was not yet being executed at the beginning of the project, so the group decided to visit the farm and study some aspects of wine bottling characteristics according to workers interviews and through a simulation of the line production. When the line was finally working, the group divided tasks among the members, to increase productivity, and was given a deadline to every task in order for the group to fulfill the plan initially defined.

2 Initial State

The Quinta Portal da Veiga is a family wine company located in Guimarães, region in the north of Portugal. The farm produces red, rosy and white "vinho verde"⁴. The winemaking process ends with the bottling of the wine, which takes place from December to March, on previously planned days, because of the long setup times required to prepare the bottling wine. Another restriction is that when the wine is transferred to the refrigeration tank, it has to be emptied by the end of each bottling day.

The current bottling line considered in this study needs five operators assigned to five processes. Before each bottling day, the bottles required for that day are washed in advance and stored in baskets as shown in Figure 1. Left, with fifty bottles each.

⁴ "Vinho verde" is the type of wine produced in the northwest part of Portugal



Figure 1. Storage of washed bottles (left); Process 1 (right).⁴

In process 1 the operator collects empty bottles from the baskets and places them in the filling machine. Once inside the machine, the filling is automatic, and each bottle always takes the same amount of wine, which is mixed with the gas. This process takes about 4.49 seconds per bottle.

The process 2 (Figure 2 on the left) also requires one operator interacting continuously with process 1, since it consists of removing the bottle from the filling machine and passing it on to the worker of the next process. This process takes about 3.99 seconds per bottle.

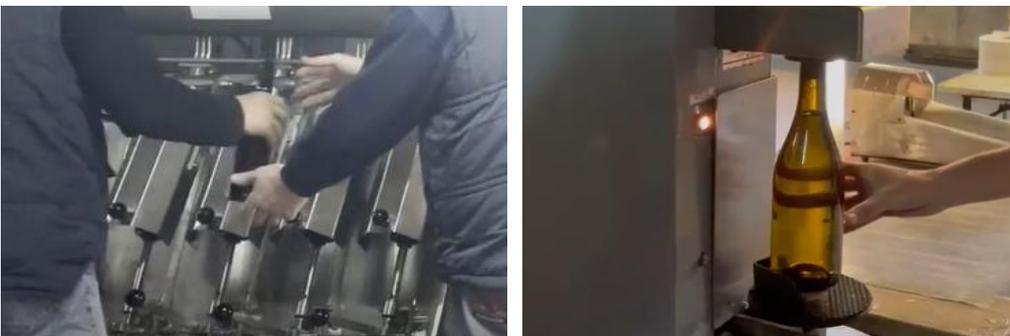


Figure 2. Process 2 (left) and Process 3 (right).

The operator in Process 3 takes the bottle that comes from process 2, places it in the bottle corking machine and presses a button to initiate an automatic introduction of a cork stopper in the bottle. This process takes in average 3.99 seconds per bottle.

In Process 4 (see left side of Figure 3) the operator collects the bottle that comes from the previous process, places a plastic capsule on the bottle neck and inserts the bottle into the bottle capsulator machine for a short period of time, so that the plastic melts and stays fixed to the bottle. The time of this process is 5.84 seconds per bottle.



Figure 3. Process 4 (left) and Process 5 (right).

Finally, in Process 5 an operator transports six bottles at a time taking them by hand to the storage location. This process has a time per bottle of 3.53 seconds.

2.1 KPIs Analysis

The line configuration presented has a *bottleneck* in process 4, resulting in a cycle time of 5.84 seconds per bottle. Table 1 presents data and KPI results from the observation and analysis of one day. Due to 5 workers hired, the productivity of 123 bottles/man.hour and the labor utilization rate of 60.53% was determined. The processing time, that is, the sum of times of all processes is 20.68 seconds, which results in a line efficiency of 70.81%. In this way the line is only able to fill 3785 bottles in an 8-hour shift, equivalent to 400 minutes of work. On the observed day 84 defective bottles were produced, so a quality factor of 97.8% was determined. The OEE (*Overall Equipment Effectiveness*) was also determined resulting in a value of 74.9% with a speed factor of 83.2% and an availability factor of 92.1%.

Table2. Data on the current state of the bottling line

Data collected	Value	KPI	Value
Number of employees	5	Line Cycle Time	5.84 seconds
Parts produced	3785	Productivity	123 bottles/man.hour
Total Processing Time	20.69 seconds	Line efficiency	70,81%
Total manpower time	17.68 seconds	Labor utilization rate	60,53%
Opening time	400 minutes	OEE	92,1%
Unplanned downtime	31.6 minutes	Availability factor	83,2%
Defective produced parts	84	Speed factor	97,8%
		Quality factor	74,9%

2.2 Waste identification

Once the operation of the line was analyzed, a VSM (Value Stream Mapp) was created, with the objective of being able to describe the whole process and identify the main problems and some existing types of waste. Given the characteristics of the business, the VSM only corresponds to the bottling period.

Customers go to the farm on average once a day and buy 2 boxes of 12 bottles. Suppliers, who are contacted by telephone call by the production manager, go to the farm only once a year and bring all the necessary stock (capsules and cork stoppers), except for the bottle supplier, which moves once a week.

Regarding the processes, 5 types of waste were identified: motion, defect, transport and overproduction. Motion waste was observed in processes 1 and 2, because operators are constantly replacing empty baskets with baskets with bottles. Defective waste occurs in all processes: in process 1 and process 2, it occurs when the filling of the bottles becomes unbalanced and the bottles become a little empty; in case 3, it is verified when the bottle explodes at the moment the cork stopper is put; in process 4, it happens when the bottle explodes, because the operator leaves it in the machine too long; in process 5, occurs when the operator drops a bottle to the ground and leaves. The waste with transport is observed in process 5, when the operator moves through the cellar to the storage area of the bottles. Finally, overproduction is wasted when it is produced first than necessary. However, this waste is considered as necessary due to the characteristics of the business.

Additionally, in addition to these wastes, one of the main problems of the line is the accumulation of WIP between process 3 and 4, because in process 4, there are actually two operations: putting the capsule and putting the bottle in the machine. Thus, the operator, before putting the bottle into the machine, always has to check that the bottle already has capsule and, while putting capsules, has to check that no bottle has forgotten in the machine, which means that it is a more time-consuming process, which marks the cadence of the line.

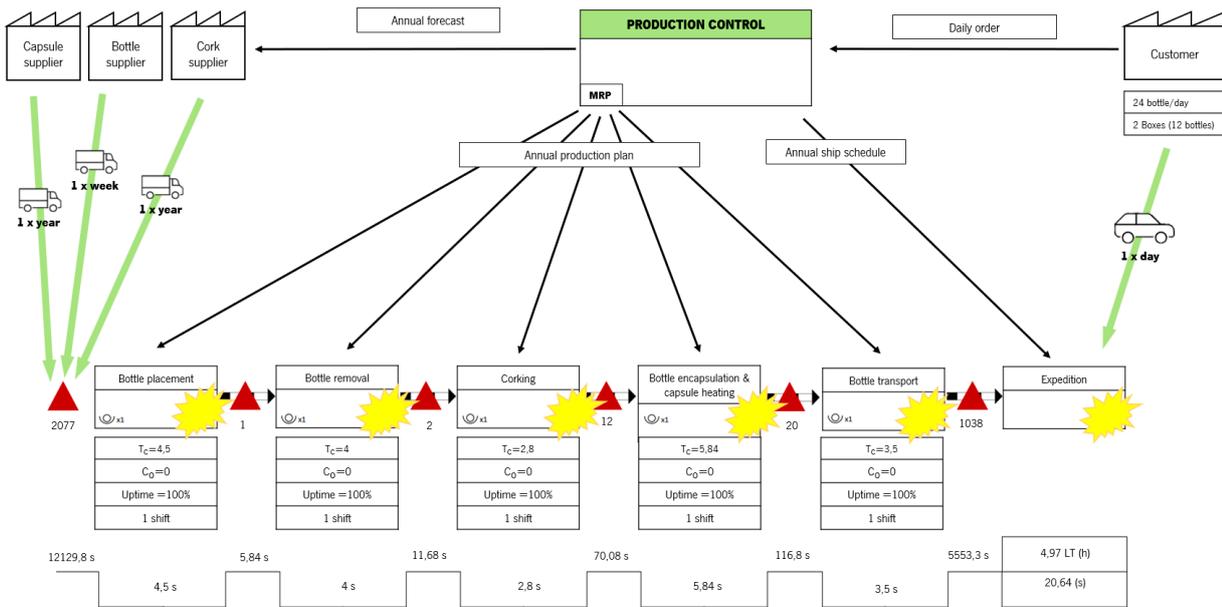


Figure 4. Value Stream Mapping (VSM).

3 Proposals for improvements

In view of the identified waste, we sought to propose solutions that would allow its elimination or its reduction. The first proposed solution is the acquisition of *fastrack wine supports*, as they take up little space and are quite stable. Given that the space for basket storage is of about 15 square meters and the proposed solution, considering 3 levels, needs about 7 square meters and would be possible to be implemented. However, an investment of €660 would be required.



Figure 5. Example of a *fastrack wine holder* (Fast Brewing & Wine Making, 2018)

In fact, this solution would reduce waste with motion in processes 1 and 2, as operators would not need to be constantly picking up a heavy basket to replace the empty baskets. In addition, it would reduce the defective waste that occurs in process 3, because with the new arrangement of the bottles, the bottlenecks would be away from each other, and the glass would always be intact. It should be noted that the arrangement of the deflating bottles of the baskets causes the necks to exert pressure on each other, which gives rise to fractures in the glass that then give in to the pressure of the cork stopper.

The second suggested solution consists of the use of two cases between processes 4 and 5, which make it possible to carry 12 bottles simultaneously. Thus, it was intended for the worker in workstation 4 to place the bottles in one of the baskets instead of placing them on the table, whereas during this period the worker in workstation 5 would be placing the bottles in the storage area. Consequently, when he returned to his post, he would have a new complete box to make a new transport. However, after implementing this solution, it

was found that the worker in post 5 had enough waiting periods and to eliminate this waste, it was considered that this worker should help the worker in post 4 to put capsules.

Having said that, in process 5, the waste with transport is reduced, since the worker can carry 12 bottles in a single movement, and the defective waste is eliminated, since the boxes prevent some bottle from falling to the ground. In addition, there is a reduction of WIP between process 3 and 4 and a decrease in the waste verified in process 4, since with the help of the worker of process 5, the worker of this process can be more focused on the bottles he puts in the machine.

In addition to the improvements implemented in the line, the 5S methodology (Hirano, 1995) was also implemented, in order to keep the winery and materials organized and reduce the cleaning time of the space whenever an unplanned stop occurs, in view of the occurrence of defects in production.

In the separation (Seiri), the necessary objects were separated from the unneeded ones. For this, the red tag strategy was used with the identification of the object and the reason for it to be discarded. In the red tag area defined, the objects must be kept for one month and then the owner of the farm must make a final decision in relation to their usefulness.



Figure 6. Implemented red tag area (left) and Organization of materials (right)

Then the space was organized (Seitou) so as to be simpler and more intuitive to find the materials, having placed some identifying papers.

Regarding cleaning (Seiso), despite the care of the workers, they usually used baskets to store the garbage and therefore the only aspect implemented was the addition of a dustbin.

For the Seiketsu (Standardize) process, visual management was used with instructions in the various spaces and in relation to the last Shitsuke (Keep), the line is responsible for naming a person who on each day of bottling, before starting the shift, verify that the 5S rules are being complied with and that the space is properly organized.

4 Futures State

The new line configuration allowed reducing the cycle time to 4.49 seconds, maintaining the same number of employees, which improves the various KPIs analyzed previously. Considering the same time of operation of the line (400 minutes), the most significant improvements are the increase in productivity to 160 bottles/man, quantity of parts produced for 4981 bottles, reduction of defective parts and the various times of operation of the line. The positive impacts are reflected in the availability factor, speed and quality, contributing to an increase in the OEE to 77.5%.

Table 2. Data on the future state of the bottling line

KPI	Value	Value
Cycle time	5.84 seconds	4.49 seconds
Number of employees	5	5
Productivity	123 bottles/hour.	160 bottles/hour.
Processing time	20.69 seconds	17.33 seconds

Total manpower time	17.68 seconds	14.33 seconds
Line efficiency	70,81%	77,18%
Labor utilization rate	60,53%	63,82%
Opening time	400 minutes	400 minutes
Unplanned downtime	31.6 minutes	27 minutes
Parts produced per day	3785	4981
Defective produced parts per day	84	67
Availability factor	92,1%	93,2%
Speed factor	83,2%	84,3%
Quality factor	97,8%	98,65%
Overall Equipment Effectiveness	74,9%	77,5%

5 Conclusion

This article, developed in real context by a group of systems engineering students in a family wine company, identified opportunities for improvement in the company under study.

The project helped students to understand the impact of lean principles and techniques application in the production process with a practical use case. Additionally, the experience contributed to understand that a successful teamwork needs a very solid communication and a distribution of tasks according team's members skills.

This work also contributed to the students learning process, with the increase of their motivation as part of a natural process with an outside collaboration and in the development of important skills for their future professional path, like critical thinking and teamwork spirit.

In this paper, the following improvements in line performance should be highlighted: decreased cycle time, significantly increase in line productivity and efficiency, decrease in defective parts per day and a very satisfactory increase in OEE in the face of implementing improvements.

In addition to the improvements verified with the monitoring of performance indicators, the lean improvements implemented, allowed workers to operate more safely in their workplace and are less subject to any accidents that may occur when a bottle leaves. The implementation of the 5S also brought significant advantages with regard to the organization of the winery, with the main benefit of speeding up unplanned stops when problems occur on the line.

Since the main objective of this project was to apply the knowledge acquired in lean classes in a practical context, the work developed falls within that scope and for that the results were successfully obtained.

The project evaluation was divided in two phases. Firstly, in the middle of the semester, the students introduced the company to the teacher, showed videos about the processes and presented some preliminary results. At the end of the semester, the final results were discussed with other systems engineering students. On both occasions, the teacher has given feedback to improve the quality of the project and provided an evaluation about the topics discussed and the level of the group communication.

Finally, the main challenge faced with the realization of the project was to overcome the resistance of employees in the face of the improvements that the group intended to implement. However, the project allowed the group to understand the concepts taught through their application in a real context.

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A Gamification Approach for Continuous Engagement in Engineering courses

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Abstract

This paper proposes an approach for continuous engagement in engineering courses using Kahoot! gamification. The main goal of the approach is increasing weekly interest in the course by providing regular assessment of the student progression in an entertaining and attractive way. For each different module of the course, a Kahoot! quiz is taken by the students to score several points proportional to the module length. The quiz includes basic questions on the topic. Points are only distributed among the top ten participants. At the end of the course, all points are summed to obtain the final classification. The course grade is increased up to 5% depending on the final position of the student. The experience aims at increasing the interest of the students and promote continuous learning from the beginning of the course. This paper describes the organization of the activities, the design of the Kahoot! quizzes, the tentative student survey to evaluate engagement and satisfaction and the quantitative assessment metrics of the proposed approach.

Keywords: Gamification; Active Learning; Engagement.

1 Introduction

Educational technology has been a matter of great importance in the last two decades, particularly in the STEM field (Chacko et al., 2015). The incorporation of alternative ways of promoting learning with current available technologies such as computer-based activities has been a priority of educational institutions. An example of this is the use of social networks such as Facebook to promote science education (Waghid, 2015) or open-source databases as Wikipedia (Meishar-Tal, H., 2015).

A very interactive way of promoting learning and engagement is gamification. This method tries to increase the student motivation by using game-thinking to solve problems (Conolly et al., 2012). Several studies have used gamification methods to increase engagement in students using a variety of platforms such as Knowingo (Welbers, et al., 2019), Class Dojo (DiGiacomo et al., 2022) or MinecrafEdu (Cózar-Gutiérrez and Sáez-López, 2016). A very simple and attractive option is the use of the Kahoot! platform. Kahoot! provides a series of learning games that include multiple-choice questions and puzzles. The use of Kahoot! gamification or similar systems has shown a significantly better performance in students' grades than those who had traditional teaching (Sarkar, Ford, & Manzo, 2017).

In this paper, we propose an approach for continuous engagement in engineering courses using Kahoot! gamification. The main goal of the approach is increasing weekly interest in the course by providing regular assessment of the student progression in an entertaining and attractive way. Some works have incorporated similar approaches to engineering courses including surveys and quantitative evaluation of certain parameters. These studies do not evaluate engagement elements and are more centered in the effect on final grades (Chernov et al., 2021) or in student satisfaction (Pertegal-Felices et al., 2020). For this reason, our proposal also includes possible metrics to evaluate how the gamification activities are affecting weekly engagement in the course contents and does not focus specifically in the effects on course performance.

This paper is divided as follows: in Section 2, the gamification methodology is explained including the structure of the activity, the design of quizzes, the scoring systems, the student survey and the evaluation metrics. Section 3 describes the possible additions to the gamification approach. Finally, Section 4 contains the conclusions.

2 Methods

In this section, we show the description of the structure of the gamification activities and the general and specific criteria to create the different quizzes. The satisfaction survey provided to the students at the end of the course is also described as well as the metrics extracted from the students' performance.

2.1 Structure of the activity

The gamification activity is divided into several quizzes (one per block) along the course, each of them with a set of 20 questions. Each course has specific characteristics and length, so the questions, distribution and score of quizzes are adapted accordingly (Figure 1). The activity is proposed for the following engineering courses in University of Alicante:

- **Service Robotics (BSc in Robotics Engineering):** This course describes the fundamentals of service robotics. A service robot is a robot that operates in a semi or totally autonomous way to provide useful services for the well-being of human beings or equipment, excluding manufacturing operations. The course is divided into 4 blocks with a Kahoot! quiz at the end of each. In a first block, the concept of human-robot interaction and the different methods available to carry it out are analyzed. In a second block, the main aspects of cognitive robotics are studied, including the analysis of cognitive architectures and cognitive human-robot interaction. The third block describes humanoid robots and aspects on locomotion of this type of robots. Finally, the last block presents the applications of service robotics in different areas, particularly centered in the use of robots for rehabilitation. Course length is divided into 15 theory lectures of 2 hours and 15 practical sessions of 2 hours (60 hours total).
- **Fundamentals of Systems and Instruments (BSc in Biomedical Engineering):** This course describes the use of systems and instrumentation in a clinical context. The course is divided into 4 blocks with a Kahoot! quiz at the end of each. In a first block, basic concepts of systems theory are introduced addressing possible clinical situations. A second block describes the main biomedical sensors used to measure human biosignals, including electroencephalography (EEG), electromyography (EMG), electrocardiography (ECG) and stimulation systems. The third block covers the application of robotics in clinical environments as for rehabilitation, assistance, surgery or motor substitution. Finally, the last block describes visualization systems in medicine and aspects of virtual and augmented reality for rehabilitation. Course length is divided into 15 theory lectures of 2 hours, 15 problem-case lectures of 1 hour and 10 practical sessions of 1 hour and 30 minutes (60 hours total).
- **Robot Control and Programming (MSc in Automation and Robotics):** This course is focused on the control and programming of robots in different environments. The course is divided into five different fields in robotics: rehabilitation robots, humanoids, robotic prostheses, space robotics and assistive robots. For each section a theoretical lecture is given followed by video examples of each topic and the Kahoot! quiz. Each section has a short introduction on the specific type of robot and aspects on how to interact and control them in practical applications. The practical contents are evaluated through a group project. Course length is divided into theory lectures up to 15 hours and 15 hours for the development of the practical project (30 hours total).

Service Robotics BSc in Robotics Engineering	Fundamentals of Systems and Instruments BSc in Biomedical Engineering	Robot Control and Programming MSc in Automation and Robotics
30% Quiz 1 – 10 questions <i>Human-Robot Interaction</i>	30% Quiz 1 – 10 questions <i>Biomedical Control Systems</i>	20% Quiz 1 – 10 questions <i>Rehabilitation Robots</i>
25% Quiz 2 – 10 questions <i>Cognitive Robotics</i>	20% Quiz 2 – 10 questions <i>Biomedical Sensors</i>	20% Quiz 2 – 10 questions <i>Humanoid Robots</i>
15% Quiz 3 – 10 questions <i>Humanoid Robots</i>	40% Quiz 3 – 10 questions <i>Medical Robots</i>	20% Quiz 3 – 10 questions <i>Robotic Prostheses</i>
30% Quiz 4 – 10 questions <i>Rehabilitation Robotics</i>	10% Quiz 4 – 10 questions <i>Biomedical Display Systems</i>	20% Quiz 4 – 10 questions <i>Space Robots</i>
		20% Quiz 5 – 10 questions <i>Assistive Robots</i>

Figure 1. Score ratio across modules for each of the courses where the methodology is or will be applied. The final score for the course is computed by multiplying quiz position by the score ratio of a particular module and summing up score for all course quizzes (score range: 0-100 points).

2.2 Design of quizzes

Kahoot! is a game-based learning platform used in educational institutions to promote additional ways of engaging students. Kahoot! provides a series of learning games that include a variety of questions such as multiple-choice, true and false, short answer, puzzles and audio questions. It also has the possibility of polling and brainstorming in a cooperative and intuitive way. Kahoot! can be accessed through a web browser or a smartphone app and allows the students to easily interact with the quiz from their seats in classroom.

For this educational experience we have proposed the use of only multiple-choice questions (4 options) to evaluate how students are following the weekly contents of each course. At the end of each block of contents, a series of 20 questions is presented to the students. Questions are divided into three categories:

- **Basic knowledge (B):** Includes basic concepts that should be known if the student has a minimal understanding of the contents of the block. This kind of questions are not expected to be included in final evaluation.
- **Advance knowledge (A):** Includes concepts that only students with a more detailed comprehension of the contents are able to know as they require a more complex reasoning. Questions of similar difficulty are included in the final evaluation.
- **Professor remarks (P):** Includes aspects that the professor has mentioned in class and that are not necessarily included in written content, i.e., slides or documentation.

A proposed question distribution for each Kahoot! quiz would be 10B, 5A and 5P questions. For quizzes that include a module with different submodules a proportional distribution of contents is advisable.

2.3 Scoring system

The proposed scoring system considers the length of each evaluated module as defined in Figure 1. For each quiz only the first 10 best students will score (10 to 1 point in descendent order). The score of the quiz will then be multiplied by the score ratio (proportion of the block divided by 10) and summed to the scores obtained in the other quizzes. The final score will give a maximum of 100 points. For example:

- If Student 1 from the Service Robotics course is 2nd in the first quiz, 6th in the second quiz, 14th in the third quiz and 10th in the fourth quiz, he/she will get a total score of $42.5 = 9 \cdot 3 + 5 \cdot 2.5 + 0 \cdot 1.5 + 1 \cdot 3$.
- If Student 2 from the Service Robotics course is 3rd in the first quiz, 4th in the second quiz, 5th in the third quiz and 1st in the fourth quiz, he/she will get a total score of $80.5 = 8 \cdot 3 + 7 \cdot 2.5 + 6 \cdot 1.5 + 10 \cdot 3$.

The final course grade is increased by a 5% if a student has the highest score of the whole course. Up to 10 students get an increase in the course grade. The student with the second highest score gets a 4.5% increase in the course grade and so on, until the 10th student who gets only a 0.5% increase in the course grade. This scoring system is intended to be proportional to the course contents and to reward not only the winner of each quiz but a fair number of students to avoid disengagement in the course of time. An additional prize for the winner can be optionally awarded. For engineering courses, we propose the 3D-printing of a trophy, medal or badge shaped in a course-related topic. This award is given to the winner by the end of the last quiz. This kind of reward is aimed at increasing the interest on this activity in the following academic years.

2.4 Student surveys

By the end of each course, students will answer to a questionnaire to evaluate aspects of engagement and satisfaction. Table 1 shows the proposed survey given to students. Each question follows a numerical Likert scale style from 1 to 10, being 1 "Strongly disagree" and 10 "Strongly agree".

Table 3. Elements of the student survey.

Type	Question
Engagement	Do you think the Kahoot!-based evaluation is a good tool to capture your interest in this course?
	Did your interest in the Kahoot!-based quizzes increased in time with each activity?
	Did this activity make you study in advance or have more interest in the contents to perform better in the quizzes?
	Did you have fun while doing this activity?
Satisfaction	Do you think the proposed Kahoot!-based evaluation is well balanced in terms of difficulty?
	Do you think the proposed Kahoot!-based evaluation is well balanced in terms of contents?
	Do you prefer this kind of activities instead of optional submissions of practical or theoretical exercises?
	Do you recommend doing this kind of activities in other courses?
	Do you think your position is fair compared to the effort you did?
	Do you think the score prize of this activity is high enough?
	Do you agree with the scoring system?
Short final answer	Do you have any suggestion to improve this activity?

2.5 Evaluation metrics

To evaluate the gamification in a quantitative way, several metrics are proposed:

Course scores

- *Average course final score*: this metric gives hints of the difficulty of quizzes for a particular group of students and can be compared to satisfaction questions from the student survey.
- *Average module correct questions*: this metric establishes which module has been more difficult for the students.
- *Average correct B questions*: this metric is useful to measure the general level of the group. B questions should be correctly answered by most of the students. If not, it could indicate a low level of competition or a proof of general disengagement.

- *Average correct A questions:* this metric is useful to measure if the lectures are of special interest to the students and how they have prepared for the quizzes.
- *Average correct P questions:* if high, this metric could indicate an especially relevant level of interest of the students to a particular course.

Fidelity

- *Number of students with all quizzes completed:* this metric establishes how many students did all the activities and shows if the gamification approach is interesting for the students.
- *Number of students completing each quiz:* together with score metrics, this parameter can help to determine if disengagement is due to difficulty and the loss of possibilities to win or is merely lack of interest.
- *Score progression of each student:* particularized to each student, this metric allows to study improvements in individual performance.
- *Average position of each student:* this metric allows evaluating how regular are students along the course.

3 Future developments

The gamification approach will be applied to the academic year 2022/2023. After evaluating the results, if positive, a pilot gamification approach will be proposed in combination with the Kahoot! quizzes in the course Robot Control and Programming within the MSc of Automation and Robotics. This course in particular is shorter than the other two and intensive, meaning that in only two weeks all the contents are given. Our proposal will include several elements to engage students:

- *Badge system:* we will incorporate a badge system to evaluate achievements during the course such as outstanding scores in specific theory and practical assignments or participation in class.
- *Video-based lectures:* in person lectures will be changed to video lectures and a flipped classroom approach will be introduced for the theory assignments.
- *Free-to-choose itinerary:* course modules will have a recommended order, but students will be free to choose which module order fits better their own interests.

4 Conclusion

This paper has described the organization of the activities, the design of the Kahoot! quizzes, the tentative student survey to evaluate engagement and satisfaction and the quantitative assessment metrics of a gamification approach to engineering courses. The main goal of this proposal is to evaluate how the gamification activities are affecting weekly engagement in the course contents and does not focus specifically in the effects on course performance. If the application of this approach is successful, more gamification elements are intended to be included in a pilot engineering course.

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Exoforge: Interdisciplinary teaching laboratory for the development of assistive technology projects

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Abstract

Today, the aging of the population and the prevalence of neuromuscular diseases make it increasingly necessary to develop technologies that improve the quality of life of these users and optimize the physical rehabilitation process. The initiative "Exoforge: Interdisciplinary teaching laboratory for the development of assistive technology projects" is proposed as a complementary training tool for engineers in the field of health technologies to cover these needs from a multidisciplinary orientation. From the teaching point of view, this initiative tries to address two essential aspects in the training of future engineers who work in the field of assistive technologies: multidisciplinary, through the incorporation of students from different degrees such as robotics engineering, biomedical engineering, or multimedia engineering; and job orientation and entrepreneurship, through the development of projects with the possibility of future transfer to a company and useful from a social point of view. This paper also describes the evaluation of the Exoforge initiative. From its creation, Exoforge has launched two different projects: ARMIA, a sensorized sleeve for upper limb rehabilitation; and ARES, a lower limb robotic exoskeleton. The main objective is to establish whether the initiative provides useful skills and tools to students within a complementary educational framework such as internships in laboratories at the University of Alicante or, where appropriate, the development of Undergraduate Thesis and Master's Dissertations related to the proposed projects.

Keywords: Active Learning; Engineering Education; Project Approaches.

1 Introduction

The number of people with congenital and/or acquired disabilities in today's Spanish society represents a large number of dependent people who lack the necessary autonomy for a fully independent life. The health technology sector is allocating a large part of its funding to provide the highest possible quality of life for these disabled people and the elderly. One of the most funded topics is the rehabilitation of the affected patient. However, according to the WHO (World Health Organisation), existing rehabilitation services have been disrupted in 60-70% of countries due to the Covid-19 pandemic. This disruption, and the need to avoid visits and attendance of patients in hospital or rehabilitation centres, reflects the importance of having competitive, reliable and accessible rehabilitation, tele-rehabilitation and home-based rehabilitation systems.

Exoforge is an interdisciplinary teaching laboratory for the development of projects in assistive technologies. It is a multidisciplinary laboratory in which students from different degrees develop projects in assistive technologies. Exoforge is a proposal that emerged within the Human Robotics research group at the University of Alicante during the 2020-21 academic year. Students participate in Exoforge through their internships as part of the curriculum of their own university degree. The participating students can come from the Degrees in Biomedical Engineering, Robotics Engineering and Multimedia Engineering, as well as from the Master's Degree in Automatics and Robotics. The main objectives of the Exoforge initiative are:

1. To develop a multidisciplinary complementary training experience for students in their final years of undergraduate and master's degrees.
2. To propose bridging experiences between educational sphere, and business and research spheres.
3. To promote innovation and entrepreneurship among students of the University of Alicante Degrees.
4. To enhance general skills such as teamwork, decision-making, personal initiative and social values and specific skills in different branches of knowledge.

Students at the Polytechnic School of the University of Alicante always have the possibility to do an internship in a company in the syllabus of their degree courses. Within the research groups of the University of Alicante,

students are offered the possibility to carry out these internships within the framework of current research projects. From the Human Robotics research group, we think that the best way to carry out these internships is through real projects that could be proposed by any company in the sector. In order to complete these projects, it is necessary to form a group of students, with great potential and who come from different degrees, that can collaborate to complement each other. The result of this proposal is Exoforge, which is similar to a company that "hires" the students. Within Exoforge, new projects are proposed every year. In the first year, Exoforge launched the ARMIA project. ARMIA is a project that develops a new wearable and wireless rehabilitation device based on an upper limb sleeve with inertial and electromyographic sensors. This device allows recording the patient's kinematic and muscular information during rehabilitation tasks and introduces telerehabilitation, a new paradigm in the process of recovering upper limb motor function. This device has significant advantages compared to other devices for motor rehabilitation. It includes low cost, small size, light weight, and wireless portability components. In the current academic year (2021-22), the development of ARMIA has continued, while a new project has been launched: ARES, a robotic exoskeleton for the lower limb.

These projects are related to the research lines of the Human Robotics research group. They are projects in which the professors of the research group can act as leaders and advisors at the same time. The idea is to take advantage of the Project Based Learning (PBL) methodology to enhance students' learning in a real project that they will be able to find in any company after graduation.

PBL is not a new teaching methodology. In (Postman, 1969) a teaching model was proposed in which lectures were abandoned and students developed their creative abilities through open questions and problems. These ideas were applied for the first time at the Mc Master University (Canada) and at the Case Western Reserve University School of Medicine (USA), where the name of problem-based learning methodology appeared for the first time. This method quickly spread through European Universities in the 1970s. It is in this decade when the Danish University of Aalborg developed a new method derived from problem-based learning: project-based learning (PBL). Currently, the PBL is considered one of the most suitable methods for the new higher education models based on active learning (Guo, 2020; Bittencourt, 2018; Guerra, 2017). With this methodology, students must assume greater responsibility, and obtain freedom of action. They will go through an active learning process that is necessary to solve the projects proposed by the teacher. PBL-based teaching is based on the development of a project that sets goals, such as the development of the final product, which achievement will require the learning of technical concepts and attitudes. The PBL methodology will only be in tune with the objectives of the European Higher Education Area (EHEA) if the student takes an active role in their learning process.

One of the main advantages of the PBL methodology is that it is developed in a real and experimental environment. This characteristic helps students to relate the theoretical contents with the real world, thus improving the acquisition of theoretical concepts. At the same time, the student takes an active role in the project and sets the pace and depth of their own learning, which makes this methodology perfectly applicable to groups with disparate base knowledge. The PBL motivates students, therefore, it can be considered as an instrument to improve academic performance and persistence in studies. Furthermore, the PBL creates an ideal framework to develop various transversal competences such as teamwork, planning, communication, and creativity (Lima, Dinis-Carvalho, Flores, & Hattum-Janssen, 2007; Powell & Weenk, 2003).

Only few works about PBL methodology in internship works are found in the literature. In (Johari, A., & Bradshaw, A. C., 2008) authors considered the roles of task, learner, and mentors as they are needed to make the most of project-based internship programs. Implications for the design and development of internship programs, and specifically successful student performance in internship programs, were also considered. Another paper describes G-DORM (Ueda, Y., et al., 2018). G-DORM is a student exchange project that has global PBL in an internship by Niigata University with four universities in Mekong countries. The paper describes the achievements of G-DORM carried out in 2017, in terms of coordination with companies for program designing, recruiting and selection of students, and implementation of internship in the student exchange program and evaluation.

2 Methodology

This section describes the methodology used in Exoforge during the last two years. Firstly, the students participating in each of the courses are described, detailing the grade they are studying. Next, the two projects launched during each course are described in more detail: ARMIA and ARES.

2.1 Participants

The students who have participated in the two courses in which Exoforge has offered internships come from the degrees taught at the Polytechnic School of the University of Alicante. The professors of the research group promoting Exoforge, Human Robotics, mainly teach on the Robotics Engineering Degree. That is why most of the students interested in participating in Exoforge come from this degree. They also teach on the Biomedical Engineering Degree, the Multimedia Engineering Degree and the Master's Degree in Automation and Robotics. In the 2020-21 academic year, Exoforge launched the ARMIA project. The aim of this project is to develop a sensorised sleeve that allows rehabilitation exercises to be carried out at a low cost and autonomously. The project mainly attracted the attention of robotic and biomedical engineers. The selection was made mainly based on the dossier provided by the candidates. Table 1 shows the number of students interested in participating, and the final number of students, from each grade who ended up participating in Exoforge during the 2020-21 academic year.

Table 4. Entry profile of students enrolled in the 2020-21 academic year in Exoforge.

Degree	Number of candidate students	Number of selected students
Robotic Engineering Degree	15	5
Biomedical Engineering Degree	8	2
Computer Science Engineering Degree	1	0
Master's Degree in Automation and Robotics	1	1

In the academic year 2021-22, Exoforge started by offering the extension of the ARMIA project. We already had a valid prototype, but we wanted to make progress in obtaining a textile sleeve that the user who was going to carry out the therapy could wear on his or her arm. In addition, the aim was to develop a serious game that, using the signals measured in the sensorised sleeve as input, would allow the exercises to be adjusted to the physical and mental fatigue of the user in the rehabilitation activities. This attracted students from the Multimedia Engineering Degree who had not shown interest in the first-year call. In addition, Exoforge has launched the ARES project for this academic year 2021-22, which consists of the design, simulation, and implementation of a knee exoskeleton. This other project is more robotic and attracted many students from the Robotics Engineering Degree. It also requires knowledge of biomechanics, which can be provided by Biomedical Engineering students. Table 2 shows the students interested by degree in participating in Exoforge during this academic year 2021-22, as well as the students who have finally participated in the two projects.

Table 2. Entry profile of students enrolled in the 2021-22 academic year in Exoforge.

Degree	Number of candidate students	Number of selected students
Robotic Engineering Degree	12	8
Biomedical Engineering Degree	6	4
Multimedia Engineering Degree	3	2

2.2 ARMIA project

ARMIA is a sensorised sleeve that allows measuring kinematics and muscular activity during upper limb movements. To determine arm kinematics three inertial sensors are placed on the kinematic chain: one on the

thorax (reference), one on the arm and one on the forearm. These last two sensors provide arm links orientation and elbow and shoulder joint angles. ARMIA does not provide wrist orientation, but it is possible to obtain Cartesian coordinates of the arm end effector (hand).

Muscular activity is measured from three of the main muscles in charge of upper limb movements: biceps, triceps and pronator teres. These sEMG sensors are used to determine the signal amplitude (contraction force) and other factors such as muscular fatigue. The instrumentation of these sensors is critical, as the bipolar electrodes must be placed parallel to the muscle fibers and close to the middle of the muscle belly, and the reference electrode must be firmly in contact with the skin.

ARMIA software is structured into three different levels. The low-level layer establishes the physical communication protocols between the different sensors and the microcontroller, and the wireless communication between the microcontroller and the computer. The medium-level layer manages the data acquisition and storage from the sensors. Finally, the high-level layer develops processing and visualization modules.

During the 2020-21 academic year, a first ARMIA prototype was developed (see Figure 1). During the academic year 2021-22, work is being carried out on a textile design for the wearable, as well as on a virtual reality application that will allow the user to carry out rehabilitation exercises.

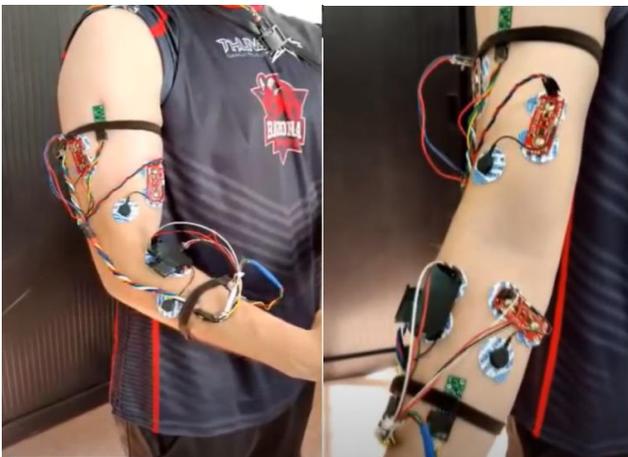


Figure 1. ARMIA prototype.

During the first course (2020-21), the students assigned to the ARMIA project were separated into three different working teams:

- Design Team (2 robotics engineering and 1 Master's Degree in Automation and Robotics students):
 - Design and implementation of the initial prototype.
- Software Team (3 robotics engineering students):
 - Acquisition and communication.
- Neuromechanics Team (2 biomedical engineering students):
 - Biomechanical study from inertial and sEMG sensors.

During this course (2021-22), the students assigned to the ARMIA project have been separated into two different working teams:

- Design Team (3 robotics and 2 biomedical engineering students):
 - Adaptation of the first prototype to a textile wearable sleeve.
- Software Team (2 multimedia engineering students):
 - Design and development of a VR serious game.

2.3 ARES project

ARES is a project that proposes the design and development of a lower limb exoskeleton. The ARES exoskeleton was created with the aim of giving users with various disabilities the opportunity to regain their mobility,

improve their quality of life and increase their autonomy. Specifically, the exoskeleton has been designed to fit a patient's leg to allow and facilitate their movement. The exoskeleton integrates inertial and electromyographic sensors to detect the signals that the brain sends to the leg. The exoskeleton processes these signals to be able to move along with the limb and, in this way, to assist the patient during walking.

The main features of the ARES device are defined below:

- Robotic exoskeleton adaptable to different leg morphologies.
- Full integration of low-cost inertial and electromyographic sensors in the device.
- Control of the exoskeleton based on ROS (Robot Operating System).
- Acquisition and calibration software for intuitive configuration and use.
- Biomechanical study of human gait for planning valid trajectories for the exoskeleton.
- Design of gait patterns to assist the patient in the development of different types of movements.

The ARES device is designed to be used both by private users to recover their mobility and autonomy, and by hospitals, clinics, therapy centers and nursing homes. ARES is a lower limb exoskeleton designed for the rehabilitation of patients with different types of disability such as spinal cord injuries, neurodegenerative diseases or those who have suffered cerebrovascular accidents. In this first phase of development, the exoskeleton has a motorized kneecap with the aim of enabling functional recovery of the knee and thus improving their autonomy.

The ARES exoskeleton adjusts to different anthropometric measurements thanks to its adaptable design. It features an adjustable knee joint extension angle, allowing the full range of knee joint movements to be limited depending on the patient's characteristics. In addition, the adjustment is simple, and the fitting, adjustment and set-up can be done in a few minutes.

In addition, the ARES exoskeleton can be used as a rehabilitation therapy to complement traditional rehabilitation by generating constant gait patterns. Its use can contribute recovering the mobility of the knee or to maintain its functional capabilities as long as possible.

A first working prototype of the exoskeleton is now available (see Figure 2). All the software development of the project is being carried out in ROS. The use of ROS, and open-source software, allows the integration of previously existing developments in perception, planning and artificial intelligence.

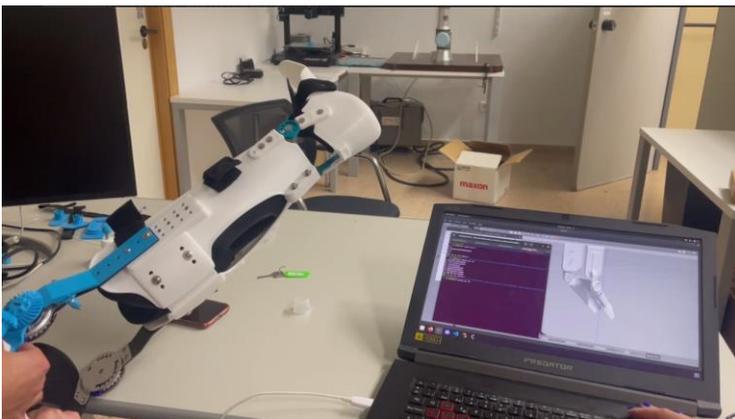


Figure 2. ARES prototype.

The students assigned to the ARES project have been separated into three different working teams:

- Neuromechanics Team (2 biomedical engineering students):
 - Study of lower limb neuromechanics and design of motor movement patterns.
- Design Team (2 robotics engineering students):
 - Adaptation of the orthosis for the motor, design and 3D printing of the robot-orthosis motion transmission.

- Control and actuation Team (3 robotic engineering students):
 - ROS control and actuation of the Maxon motor via Ethercat, and motion pattern tracking.

3 Exoforge evaluation

For the drafting of the survey to evaluate different aspects of the methodology, we first thought of the items that were most interesting to know. A very important aspect to know was the group cohesion achieved, since all the work for the development of the project is divided into different work teams. Students were also asked for their opinion on whether they found the Exoforge experience useful, or whether it allowed them to apply the knowledge acquired in their degree, if the motivation has been increased or not, etc. Another important question to be evaluated is whether their time at Exoforge has given them any ideas for the development of their final degree project. The questions asked can be seen in Table 3. The survey was conducted through a questionnaire using Google Forms. This survey was anonymous, although as described in Section 2.1, the total sample is known, given that they are the students who have participated in the Exoforge experience. Although 18 students participated in the experience, only 11 answered the survey.

Table 3. Survey for the Exoforge initiative student opinion.

Q1	Do you feel you have learnt anything from working at Exoforge?	Yes	No
Q2	Have you been able to apply concepts seen in any of the subjects of the Degree in Exoforge?	Yes	No
Q3	Do you consider that the time spent on external internships is sufficient to carry out your tasks within Exoforge?	Yes	No
Q4	Do you consider that the guidance provided by the teachers for the resolution of the project has been adequate?	Yes	No
Q5	Doing my external internship at Exoforge has allowed me to define an idea for my Final Degree Thesis dissertation	Yes	No
Rate from 1 (a little) to 9 (a lot):			
Q6	The work methodology proposed in Exoforge has made me feel motivated.	1	2 3 4 5 6 7 8 9
Q7	The work methodology proposed at Exoforge promoted teamwork.	1	2 3 4 5 6 7 8 9
Q8	I have learned how to make a detailed planning of the time to be spent on each of the tasks required to complete the project	1	2 3 4 5 6 7 8 9
Q9	I have learnt how to carry out an analysis and design prior to project implementation	1	2 3 4 5 6 7 8 9
Q10	I have learnt to search for information on my own for the implementation of the project	1	2 3 4 5 6 7 8 9
Q11	I have learnt to work in a group and actively participate in the project	1	2 3 4 5 6 7 8 9
Q12	I am satisfied with the work we can do in the group formed in Exoforge	1	2 3 4 5 6 7 8 9
Q13	I like the working atmosphere of the group formed in Exoforge	1	2 3 4 5 6 7 8 9
Q14	I am satisfied with the amount of work being done at Exoforge	1	2 3 4 5 6 7 8 9
Q15	I am satisfied with the ideas that the members of the Exoforge group bring to the table when we work together	1	2 3 4 5 6 7 8 9
Q16	When one member of Exoforge's group doesn't understand something, the others try to explain it to him or her ---	1	2 3 4 5 6 7 8 9
Q17	The members of my group prefer to work together rather than working individually	1	2 3 4 5 6 7 8 9
Q18	Doing my internship at Exoforge gives me a work experience close to reality	1	2 3 4 5 6 7 8 9

The results of the survey are very encouraging. We will now review the results for each question. In the first question, the students unanimously indicate that they have learned something during their time at Exoforge (100%). Also, all students (100%) say that they have been able to apply the concepts seen in their degree courses during the 150 hours they have spent on the external internships carried out at Exoforge. Once again, all the students (100%) who answered the survey indicated that the 150 hours were sufficient to carry out the tasks that were planned at the beginning of the internship at Exoforge. With regard to question 4, the students also unanimously indicated that the lecturers have given them adequate guidance in the development of the proposed project (100%). Question 5 is the last Yes/No question. The idea behind this question was to obtain information on whether the students have seen or detected any ideas for a final degree project to be carried out based on the developments made in Exoforge. More than half (54.5%) answered in the affirmative, which seems to us a very interesting aspect, as Exoforge can become a seed for the development of small individual projects that enhance the experience started in the internships.

The first block of questions (Q6, Q8, Q9, Q10, Q14, Q18) with 11 possible Likert-type answers deals with the opinion of each student's individual work in Exoforge. For each question, students answer a value from 0 to 10 indicating a little (0) to a lot (10). Figure 3 shows the answers obtained for this first block of Likert-type questions. The answers are positive for all the questions in this block. Specifically, when asked whether the Exoforge methodology has motivated them, the majority indicate values between 8 and 10 (90.09%), with one isolated case indicating 5. All students indicate that the methodology used has helped them to some degree to learn to plan the time used for each task (with 100% indicating values between 7 and 10). The same happens when questioned about whether the methodology has helped them learn about the importance of prior design and analysis before starting to programme or develop tasks (also with 100% in values between 7 and 10, although in this case more than half 6/11 voted values of 9 and 10). Encouraging responses were also seen in question 10. The students claim to have learned to search for information on their own to solve the various tasks assigned in the project (7/11 voted values of 9 and 10). In question 14, the majority of students say that they are satisfied with the work carried out in Exoforge (9/11 voted 10, the other 2 voted 8). Finally, they were asked whether they think that the work done at Exoforge gave them an experience as close as possible to what they might find in the world of work. This is where we found the greatest disparity in the responses, although always with positive values (between 5 and 10).

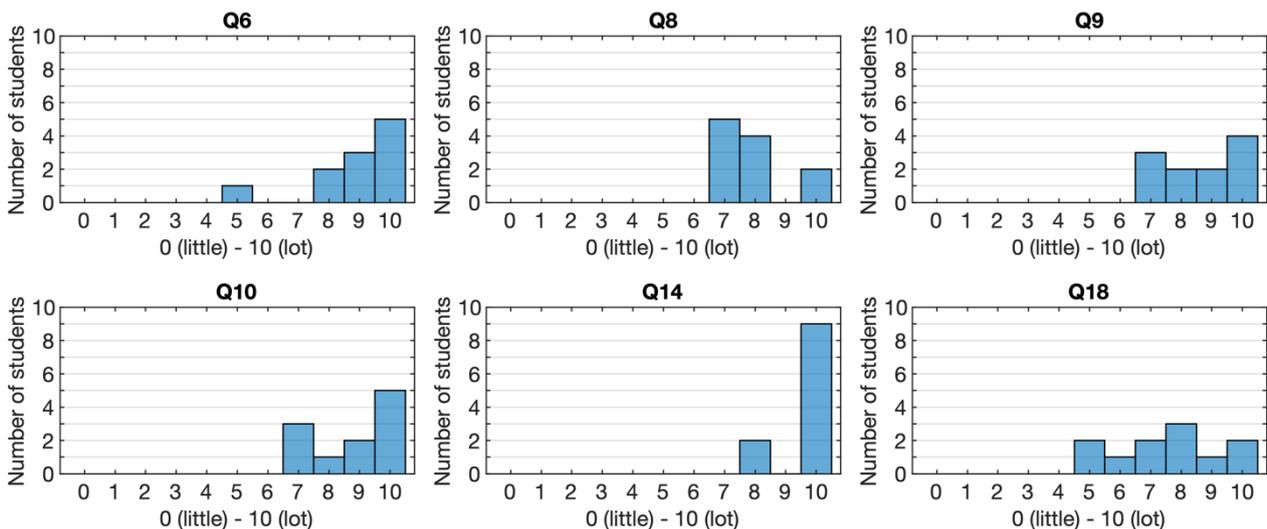


Figure 3. Answers for Questions 6, 8, 9, 10, 14 and 18 of the survey.

The second block of questions (Q7, Q11, Q12, Q13, Q15, Q16 and Q17) with 11 possible Likert-type answers deals with group cohesion and group functioning. Figure 4 shows the answers obtained for this second block of Likert-type questions. Again, the answers are positive for all the questions in this block. To begin with, in question 7, 9 of the 11 students who filled in the survey say that working at Exoforge encouraged teamwork (they voted values of 9 and 10). Of particular interest is question 11, where all students indicate that they have learned to work in a team because of their experience at Exoforge (all voted 8-10). The same is true for question 12, with all 11 students voting between 8 and 10, with 7 of the 11 voting 10 on the question of whether they

are satisfied with the work that can be done by the group formed in Exoforge. The working atmosphere is undoubtedly the most highly valued aspect of the survey, with 9 of the 11 students voting 10, and the other two, 8 and 9. The ideas contributed by the other members of the group to solve the problems encountered throughout the project are also highly valued (9/11 voted 9-10). Question 16 asks about companionship, asking whether the members of the group help someone who has not understood concepts to understand them (all students voted 8-10). Virtually all students indicate that others prefer to work in groups rather than individually (only one student voted 4, the rest 8-10).

4 Conclusion

The Exoforge initiative has allowed students from the Polytechnic School of the University of Alicante to carry out their internships for two academic years in technological projects for the rehabilitation of upper and lower

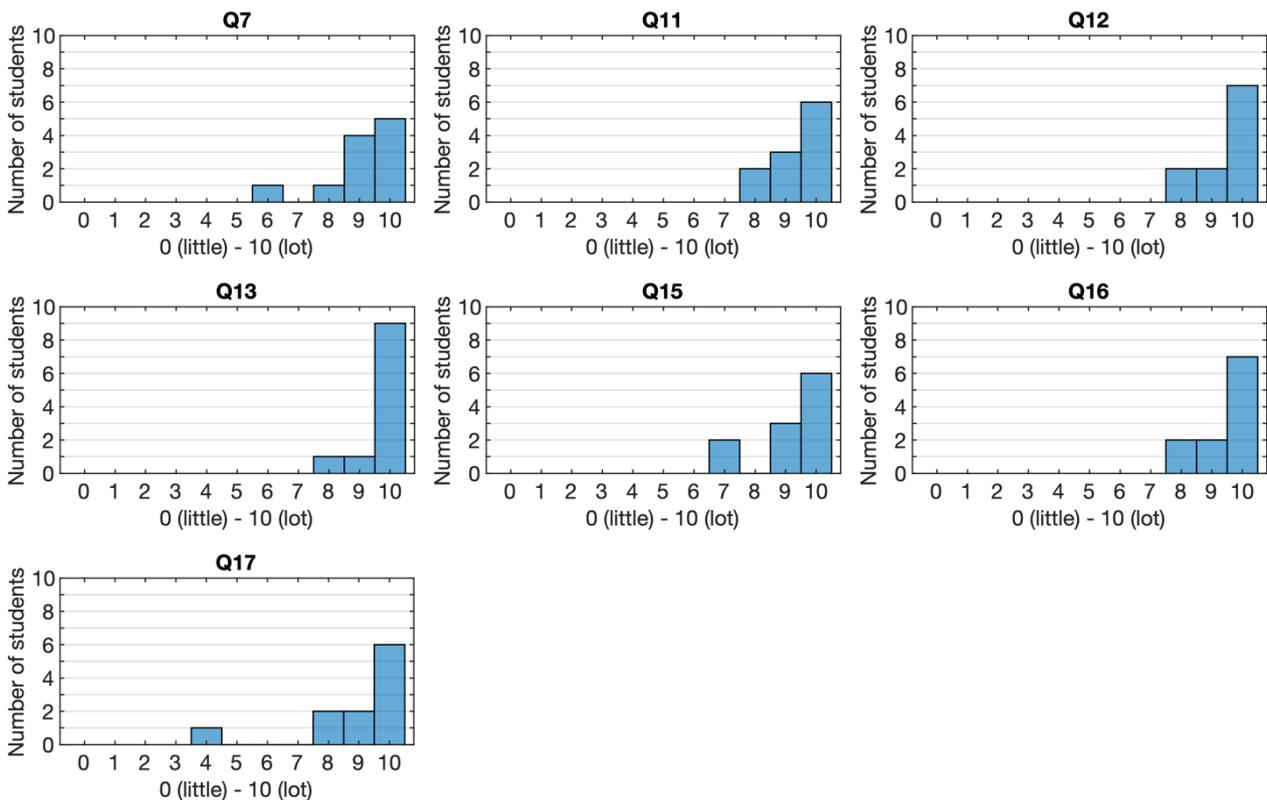


Figure 4. Answers for Questions 7, 11, 12, 13, 15, 16, and 17 of the survey.

limbs. The result of the first course (2020-21) was a success, obtaining a valid prototype of a sensorised sleeve that allows obtaining kinematic and electromyographic information during the rehabilitation task. In addition, this project, the ARMIA project, won the Impulso 2021 Prize for Accessibility, awarded by the University of Alicante. In this second course of the Exoforge initiative, ARMIA continues to develop the initial prototype to make it more "wearable", while a serious game for virtual reality is being developed to gamify the rehabilitation therapy exercises. In addition, during this academic year, the ARES project has been launched, in which a first functional prototype of a low-cost knee exoskeleton has already been obtained. This exoskeleton is controlled by free software and has a series of sensors that allow estimating the user's movement intention to improve the quality of rehabilitation and/or walking assistance. The survey carried out among the participating students shows excellent results. A great group cohesion in teamwork is observed, as well as great satisfaction in participating in the projects offered by Exoforge. More than half of the students are even considering continuing to develop tasks for Exoforge as part of their own final degree projects.

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Exploration of the use of Project Based Learning (PBL) methodology in two accredited engineering programs at the Autonomous University of Yucatán

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Abstract

The aim of this work was an exploratory qualitative investigation of the use of the PBL methodology in two currently accredited undergraduate programs at the Faculty of Chemical Engineering of the Autonomous University of Yucatan: Industrial Chemical Engineering (IQI) and Industrial Logistics Engineering (ILL). Project Based Learning (PBL) is considered today as one of the most effective methods in engineering education, because it allows students to develop competencies and skills that are increasingly demanded by organizations to new professionals and trainees. The methodology consisted of consulting the programs of the mentioned degrees and courses, in particular the didactic plans elaborated by the professors of each subject in order to select those that use project-based learning as an evaluation instrument. An exploration instrument was applied to students of the last semesters, with the purpose of knowing if this methodology is reaching its objectives and if the student has knowledge of the project-based learning methodology. The results showed that 72% of the curricula of the Industrial Logistics Engineering career apply this methodology (PBL) and 52% in Industrial Chemical Engineering. In conclusion, it was observed that a significant number of subjects in the undergraduate courses studied use project-based learning as a product for evaluating course performance; however, the PBL methodology is used empirically.

Keywords: Project Based Learning; Programs; Didactic plans; Accredited; Engineering.

1 Introduction

Traditionally, education has been fundamentally centered on teaching, and with it on the teacher as the axis of the teaching-learning process. Now, this change entails giving students a greater role, putting all efforts into their learning, relieving the role of the teacher to that of guide and orientor. Thus, the more behaviorist and cognitivist theories give way to constructivist theories, developing meaningful learning in students (Carrasco, Donoso, Duarte-Atoche, Hernández & López, 2015; Muñoz & Díaz, 2009; Navarro, Pertegal, Gil, González & Jimeno, 2011), in which the knowledge they already possess is integrated with the new knowledge they must acquire, making what they have learned last over time. It is not so important what the student knows at a given moment, but what he/she may come to know, which is closely related to his/her learning capacity (Estruch and Silva, 2006). More important than learning content is learning to learn, fostering continuous learning (Reverte, Gallego, Molina and Satorre, 2006; Taboada, Touriño and Doallo, 2010). Learning can be seen as a cumulative, self-regulated, directed, collaborative and individual process (Van den Bergh et al., 2006).

Project-based learning (PBL) appears to be an effective teaching method compared to traditional cognitive teaching strategies, particularly for the development of real-life problem-solving skills (Willard & Duffrin, 2003).

Project-based learning is a methodology that is developed in a collaborative manner that confronts students with situations that lead them to put forward proposals to address certain problems. By project we understand the set of activities articulated with each other, in order to generate products, services or understandings capable of solving problems or satisfying needs and concerns, considering the resources and time allocated. Authors and researchers who propose competency-based models in education consider that the project is an integrative strategy par excellence, and that it is the most appropriate to mobilize knowledge in situation (Díaz Barriga 2015; Jonnaert et. al. 2006). In this way, students can plan, implement and evaluate activities with purposes that have real-world application beyond the classroom.

Project-based learning has many benefits, among others, the possibility of continuous feedback and evaluation by the teacher, the establishment of a schedule of activities that show the progress of the different groups, generating a space for reflection by the student, preparing them for their professional and labor future, increasing motivation and involvement of both students and teachers. It increases their social and communication skills, improves problem solving and they learn to work in groups (Collazos, 2009). In addition, it promotes creative thinking and decision making, fostering higher academic performance. Bearing all the above in mind, it can be stated that PBL facilitates the learning of new knowledge and allows the application of the already acquired knowledge, develops transversal skills, including planning, writing, communication, as well as the responsibility to face a real situation (Carraco et al., 2015).

Nowadays, society requires an innovative engineer, bold in experimentation, with skills of interaction and exchange of ideas with other professionals from different areas (Duque & Martínez, 2000). This implies the establishment of a solid academic-cultural community, which breaks with the mental schemes that generate a presumed separation between scientific knowledge and humanistic knowledge. There is no point in training academic engineers who are alien to human sensitivity, just as there is no point in graduating artists without any hint of scientific rigor. Engineering is the conceptualization, design, construction and administration of projects and products aimed at providing a solution to a need of society or the environment. For this reason, the engineer must solve problems or provide different solutions, which requires imagination, creativity and synthesis of knowledge (Duque et al., 1999). Engineering, in general, is a decision-making process for the solution of problems within a particular field of action. This decision making involves different steps, among which the following stand out: delimiting the situation, proposing a solution strategy, obtaining experimental or theoretical information, analyzing the data and results, selecting the valuation criteria for the possible solutions, choosing the optimum variable and correcting the decision during its implementation (Garza-Rivera, 2001).

In response to the national and global needs of the integral formation of an engineer, capable of developing in the labor field, so that he develops skills and abilities to solve problems or provide different solutions, given this is why the Autonomous University of Yucatan (UADY), prioritizes the continuous professional training of students, through its educational programs taught in the Faculty of Chemical Engineering (FIQ), making use in recent years of the PBL methodology, as a method to obtain a competent learning for students who graduate and can perform satisfactorily in the labor field. Therefore, it is necessary to know and identify the results, effectiveness and contribution of the project-based learning methodology in the accredited programs of the faculty, taking as a sample the last semesters of the degrees of; Industrial Chemical Engineering and Industrial Logistics Engineering.

2 Objective

- Identify which subjects of the curriculum of each degree program declare in their didactic plans the use of the PBL methodology as an evaluation tool.
- Determine if students know the project-based learning methodology and if they have used it in any subject in order to know the impact and effectiveness it has had in the acquisition of new competencies for professional development.

3 Methodology

Considering that the research is qualitative and exploratory, it was established that the sample size for this exploration is 30 cases (Hernandez, Fernandez and Baptista, 2010), by degrees made up of eighth and tenth semester students, i.e. there will be 30 cases in total for students of the degree of Industrial Chemical Engineering and Industrial Logistics Engineering.

The first part of the research consisted of the exploration of the descriptive letters of the two accredited bachelor's degrees under study, which were consulted through the official website of the Faculty of Chemical Engineering of the UADY, which is shown in the following figure:

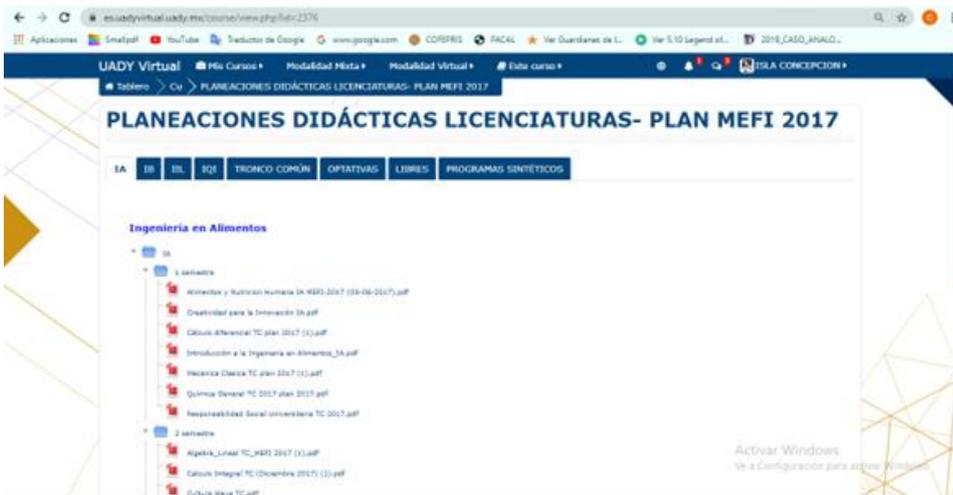


Figure 1. Portal de los planeaciones didácticas de los programas analizados

Subsequently, the results obtained from the descriptive charts consulted were compared with those found in the Moodle platform, which is used to support face-to-face classes by both teachers and students. On this platform, students can consult the guidelines for each of their subjects, including the topics, learning activities and the final evaluation method of the course.

The second part consisted of the application of a survey-type evaluation instrument using a Likert scale to the students to determine if they know and use project-based learning and how it impacts their training and the acquisition of skills.

The survey contains eight questions and was created using the Google Drive forms tool to make it easy to apply via email. Two important sources were used as a guide for the creation and adaptation of the evaluation survey (Carrasco, A., et al. (2015) and Rodríguez A., Río R, and Larrañaga J. (2016)). It should be noted that the exploratory research includes as a sample only students from the last two years of the degree.

3.1 Survey

1. ¿Have you heard of the Project-Based Learning (ABP or PBL) methodology?
 - Yes
 - No

2. Select the subjects in which you carried out a project in a real company:
 - for ILL students the possible options were:
 - Safety and industrial hygiene
 - Methods Engineering
 - Project management
 - Supply chain management systems
 - Warehouses and inventories
 - Formulation and evaluation of processes
 - Supplying
 - Marketing and customer service
 - Planning and control of operations
 - Strategic planning
 - for IQI students the possible options were:
 - Integrative project I
 - Integrative Project II

- Industrial engineering
 - Economic engineering
 - Process control
 - Service engineering
 - Process design
 - Process integration
 - Safety and industrial hygiene
 - Separations by continuous contact
 - Fundamentals of industrial engineering
3. ¿Mention if you have taken the (PBL) in subjects other than those selected above?
- Open answer
4. ¿Do you think that teamwork allows you to increase your motivation to learn or do you prefer to work individually?
- Yes
 - No
 - I prefer work individually
5. ¿Your teachers were available to give you support and help you solve any doubts about the project?
- Totally agree
 - I agree
 - Neither agree nor disagree
 - Disagree
 - Strongly disagree
6. ¿What do you think was the biggest obstacle you had to overcome to carry out a project of this type?
- Communication skills
 - Time
 - Little access to the company
 - Unknowing of the objectives
 - Others
7. ¿What kind of skills do you consider to have developed in the projects in which you were involved?
- Leadership
 - Critical thinking
 - Autonomous learning
 - Conflict resolution
 - Collaboration
 - Creativity
 - Troubleshooting
 - Listen active
8. ¿Do you feel that the projects are relevant to your professional future?
- Totally agree
 - I agree
 - Neither agree nor disagree
 - Disagree
 - Strongly disagree

4 Results

4.1 Analysis of the didactic plans

Once the exploratory research was initiated, the descriptive letters and didactic plans of the five undergraduate courses offered by the School of Chemical Engineering were consulted, with the intention of finding out which subjects of their curricula declared the use of Project Based Learning, and the results were the following.

The first point was to determine the total percentage of the use of this methodology at a global level, that is to say, considering all the subjects taught in the five degree courses. It was found that 53% of the subjects contemplate the implementation of PBL within their descriptive charts, according to the figure below:

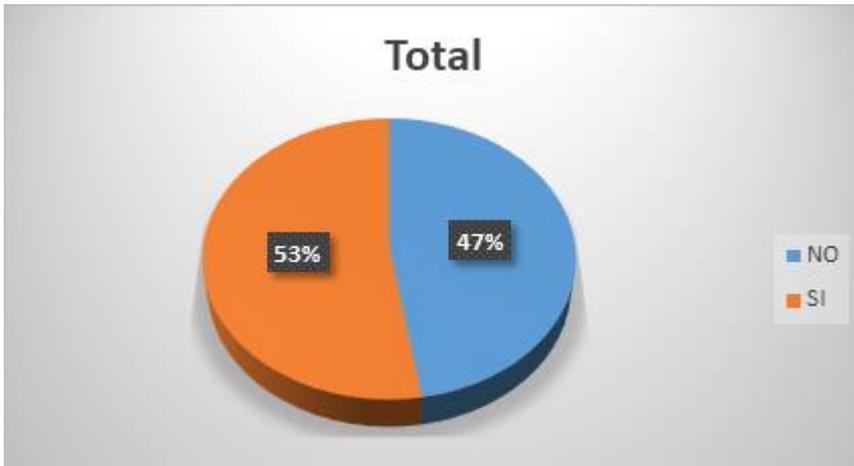


Figure 2. Overall percentage of subjects that reported using PBL as a learning technique..

Subsequently, of the total number of subjects that apply the PBL, the total percentage that corresponds to each degree program was explored, that is, out of a total of 123 subjects that apply this methodology to evaluate, the Industrial Logistics Engineering (IIL) degree program has 28%, resulting in the fact that, comparing all the degree programs, this is the one that applies this methodology the most, and Industrial Chemical Engineering (IQI), 21%, placing it in third place. This distribution is shown in the following figure:

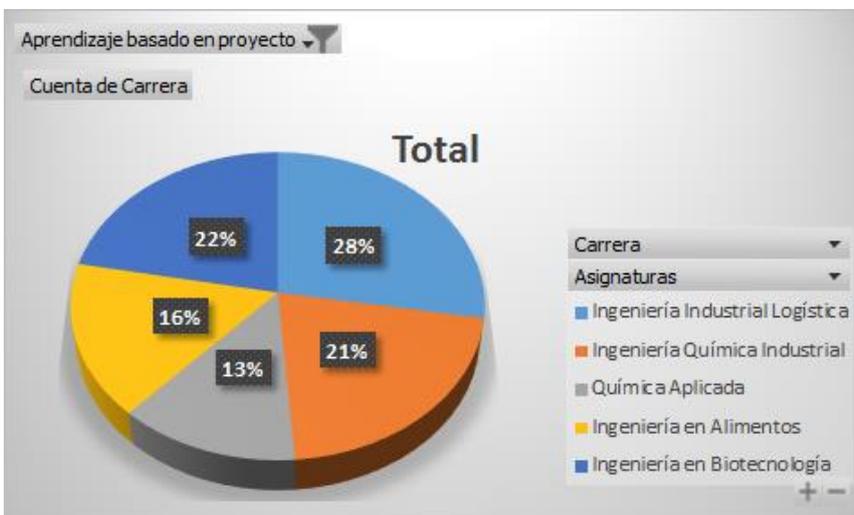


Figure 3. Percentage of subjects that have reported using PBL as a learning technique, in each of the degree programs offered..

Taking these results into account, we proceeded to explore the undergraduate programs being evaluated, which are currently accredited by the faculty. Beginning with the analysis of the Industrial Logistics Engineering degree, the figure below shows the total percentage of use of this methodology by subject. This analysis shows that 72% of the subjects in its curriculum implement Project Based Learning. That is to say, 34 subjects state in their descriptive letters and didactic plans that they evaluate student learning through this study method, of the 47 that make up the curriculum.

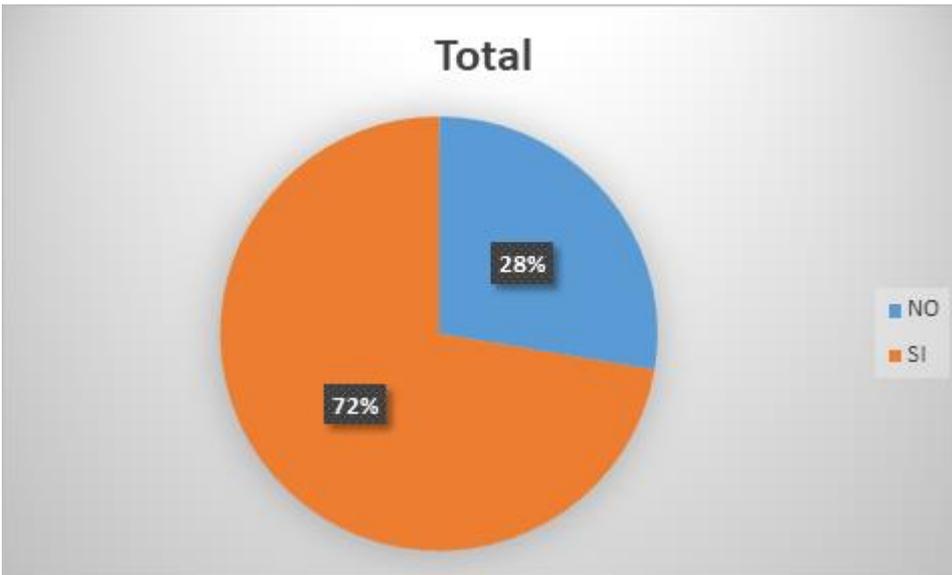


Figure 4. Percentage of subjects that have reported using PBL as a learning technique in the Industrial Logistics Engineering plan.

In order to have a clearer idea of the distribution throughout the proposed training, the following graph shows the number of subjects that make use of it by semesters of the bachelor's degree under study.

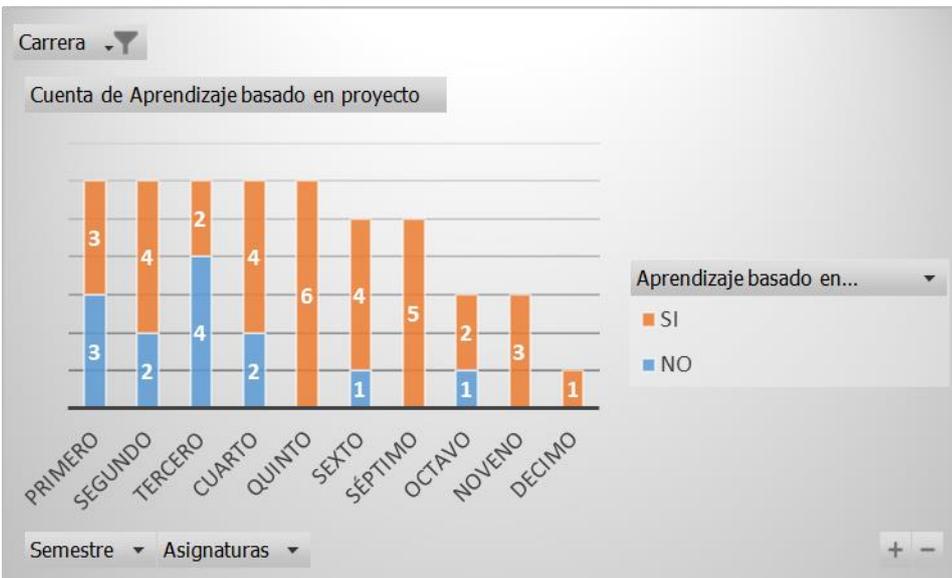


Figure 5. Percentage of subjects that have reported using PBL as a learning technique in the Industrial Logistics Engineering plan, by semester.

Continuing with the analysis, we move on to the Industrial Chemical Engineering degree. In the figure below we can see that 52% of the subjects in its curriculum state that they implement this Project Based Learning methodology as an evaluation method. That is to say, out of its 50 mandatory subjects, 24 declare that they use this methodology.

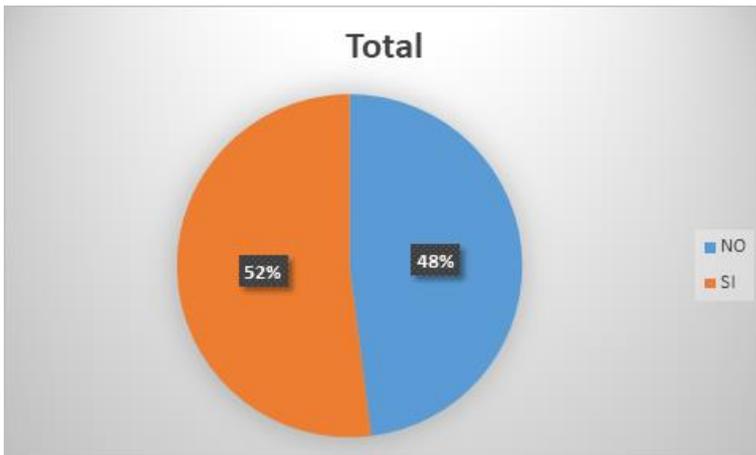


Figure 6. Percentage of subjects that have reported using PBL as a learning technique in the Industrial Chemical Engineering plan.

In order to have a clearer picture of the distribution, the figure below shows the number of subjects that make use of the methodology (PBL) per semester, in the case of Industrial Chemical Engineering. It can be seen that the semester in which this evaluation method is most used is the eighth semester.

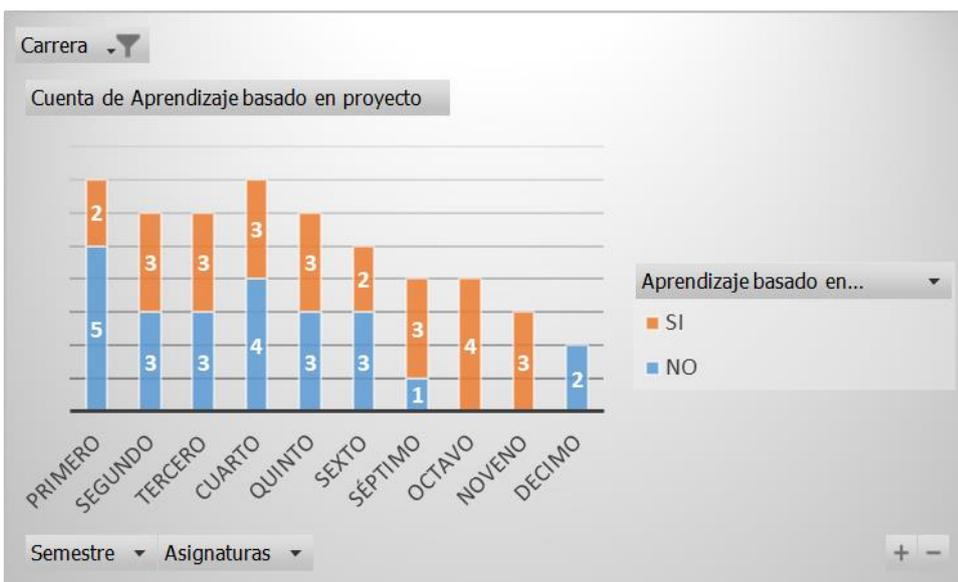


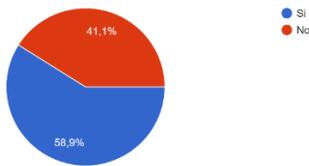
Figure 7. Percentage of subjects that have reported using PBL as a learning technique in the Industrial Chemical Engineering plan, by semester..

Once the results of the exploration of the descriptive letters and the didactic plans were obtained, the evaluation instruments were applied in order to measure their effectiveness and the impact they are having..

4.2 Analysis of student perceptions

Figure 3 shows the percentage of knowledge that students have in the use of this methodology. In the case of the students of the Logistics Industrial Engineering program (IIL), 58.9% know the PBL methodology, as well as 53.4% of the Chemical Engineering students (IQI).

¿Has escuchado hablar de la metodología de Aprendizaje Basado en Proyectos (ABP o PBL)?
56 respuestas



¿Has cursado alguna materia que utilice la metodología didáctica de Aprendizaje Basado en Proyectos (ABP o PBL)?
73 respuestas

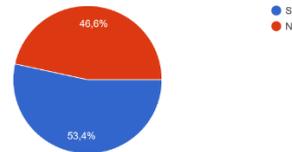
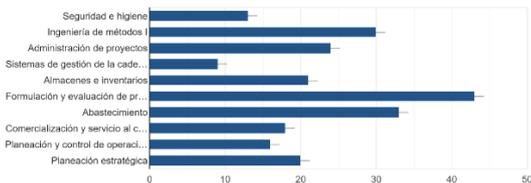


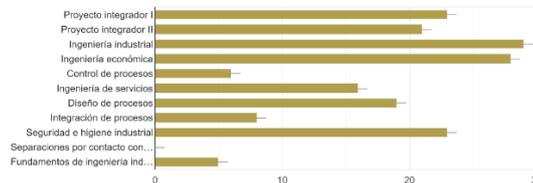
Figure 8. Results of question 1 regarding knowledge of the methodology for IQI and IIL respectively.

The subjects that apply the PBL technique. For the Industrial Logistics Engineering (IIL) degree, Methods Engineering, Project Formulation and Evaluation and Supply stand out. For Industrial Chemical Engineering (IQI), none of the subjects presents a response that exceeds 50% as shown in the next figure.

Selecciona las asignaturas en las que llevaste a cabo un proyecto en una empresa real
56 respuestas



Selecciona las asignaturas en las que llevaste a cabo un proyecto en una empresa real
73 respuestas



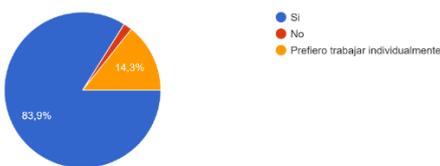
IIL

IQI

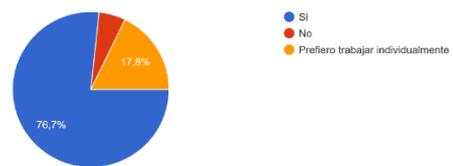
Figure 9. Asignaturas que en sus planeaciones contemplan la técnica ABP y que los alumnos reportan haberla utilizado. IIL en azul e IQI en dorado.

According to the results presented in the next figure, more than 75%, in both careers, are convinced that teamwork motivates them to learn

¿Crees que el trabajo en equipo te permite aumentar tu motivación para aprender o prefieres trabajar individualmente?
56 respuestas



¿Crees que el trabajo en equipo te permite aumentar tu motivación para aprender o prefieres trabajar individualmente?
73 respuestas



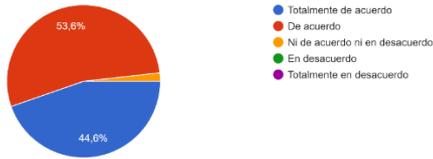
IQI

IIL

Figure 10. Perception of students in relation to intrinsic motivation for teamwork.

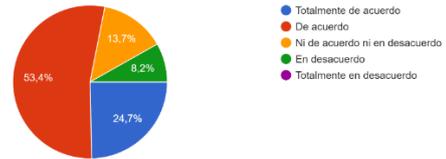
The presence of the teacher with the students is necessary when using this technique. The accompaniment of the teacher provides certainty that translates into better achievement results. That was expressed by students from both programs.

¿Tus profesores estuvieron disponibles para brindarte apoyo y ayudarte a resolver las dudas del proyecto?
56 respuestas



IQI

¿Tus profesores estuvieron disponibles para brindarte apoyo y ayudarte a resolver las dudas del proyecto?
73 respuestas

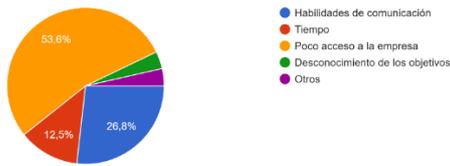


IIL

Figure 11. Presence of teachers during the development of the project.

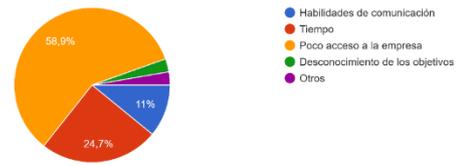
In the case of the challenges presented by the PBL technique (next figure) for the students of the Industrial Chemical Engineering program, the predominant factor is access to the company (53.6%) similar to the appreciation of the students of Logistics Industrial Engineering (58.9 %). On the other hand, for Chemical Engineers, the second factor that represents a challenge is communication skills (26.8%), which are the third factor for students of Logistics Industrial Engineering (11%) and vice versa, the third for IQI is the time factor (12.5%) which for IILs is the second element (24.7%).

¿Cuál crees que fue el más grande obstáculo que tuviste que vencer para realizar un proyecto de este tipo?
56 respuestas



IQI

¿Cuál crees que fue el más grande obstáculo que tuviste que vencer para realizar un proyecto de este tipo?
73 respuestas

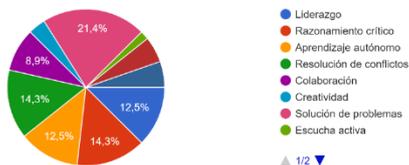


IIL

Figure 12. Challenges to overcome in the elaboration of the Project

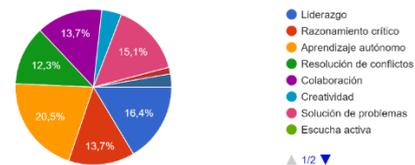
In relation to the skills developed during the development of the project, although they have different views, it is interesting to observe that they recognize the development of different skills as shown in the next figure.

¿Qué tipo de competencias consideras haber desarrollado en los proyectos en los que estuviste involucrado?
56 respuestas



IQI

¿Qué tipo de competencias consideras haber desarrollado en los proyectos en los que estuviste involucrado?
73 respuestas

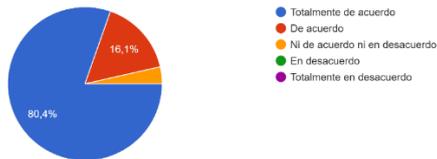


IIL

Figure 13. Competences developed during the use of PBL as a learning method.

An important percentage (80.4%) of the IIL recognize that the development of projects as a learning technique is relevant for their professional future, while only half of the IQI students recognize this relationship.

¿Sientes que los proyectos son relevantes para tu futuro profesional?
56 respuestas



¿Sientes que los proyectos son relevantes para tu futuro profesional?
73 respuestas

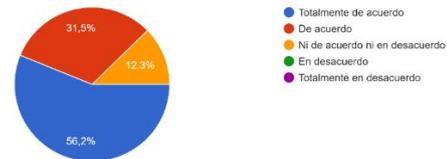


Figure 14. Perception of the relationship between the skills developed and professional practice.

5 Conclusion

In general, we can conclude that the PBL technique is used as a learning model in the programs studied. From the results obtained we can establish that a greater use of the technique for the acquisition of knowledge is needed. As well as a more punctual presence of the teacher when this technique is proposed as a learning method.

In both study plans it is necessary to deepen the use of this technique and to integrate it in the last semesters so that learning has an even greater impact. It is necessary to reorient the strategies and deepen the research trying to discriminate those courses that use the methodology and those that remain superficial. This in order to be able to answer the question generated by the declared percentage of use of the technique versus the percentage of appreciation on the part of the students.

On the other hand, students recognize that the technique has an impact on several skills that will be useful during their professional practice. However, **it is not used in a systematized way by students or teachers**, in this work we only inquired with students who develop projects in real scenarios as part of the product of their subjects, but in an empirical way they actually apply it without the knowledge that there are a series of steps to follow.

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The use of games in the teaching of Production Engineering: a list based on publications in Scopus

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Abstract

The use of games in the teaching of production engineering is on the rise since it allows the presentation of knowledge and its absorption in a more relaxed way, it helps the development of essential skills for a good professional as well. As a way of identifying educational games developed, used and/or published in production engineering courses, a qualitative research was carried out on the Scopus database. The research returned 40 publications, of which 11 could not be accessed and only 18 had games related to the course in question. As a result, 44 games were compiled, which were listed in order to facilitate their knowledge by teachers in the area, stimulating their application and the modernization of teaching.

Keywords: Educational Games; Production Engineering; Game-based Learning; Game List.

1 Introduction

The advancement of technologies, the dynamics of the modern world, the sharing of information in real time, the adaptation needs, among other issues, caused the students' profile to be significantly changed (RUBEUS, 2021).

In this way, the traditional teaching-learning strategies are no longer sufficient for this profile that seeks more condensed and faster information. Evidence of this fact is that much has been studied and developed in relation to active methodologies.

The active learning methodology is any educational approach in which students actively participate in the learning process, becoming the centrepiece of the process and the main responsible for their learning (Lázaro et al., 2018). They encourage debates and practice, as well as the review of knowledge through explanations with other students. Some of the main active methodologies are: Project-Based Learning, Problem-Based Learning, Gamification, Game-Based Learning (GBL).

With the world increasingly dynamic, the GBL has proved to be a good teaching tool, since it uses games to generate greater engagement, motivate action, promote learning or solve problems in a creative way, in the case of an excellent way to help students lose resistance in the face of complex topics (Sales et al., 2017).

It turns out that the application of games implies the need for development or knowledge of the existence of the game on the part of the teacher as well as in its study. Although the absence of games was a problem a few years ago, today there are already several games that can be applied in teaching different subjects and courses. However, finding a game suited to a specific subject, discipline or competence is often hard work that inhibits the adoption of the GBL (Bonetti, 2014).

In order to facilitate and encourage the use of games in the teaching of Production Engineering, this research presents a list of games found in national and international publications.

2 Methods

This bibliographic research was carried out by searching the titles of Scopus publications, using the following keywords: game AND engineer* AND (product* OR manufact* OR industrial). The search resulted in 40

publications, of which 11 could not be accessed and only 18 had games related to Production Engineering. After analysing the publications found, 44 games were identified.

Although it would be desirable to present a detailed description of the games, including the number of players, application time, the skills worked, among others, the lack of standardization in the data presented limited the study to presenting few characteristics (name, description, access, format and areas/subjects addressed), listed in table 1.

Therefore, this is a bibliographical, qualitative and exploratory research that aims to identify games that can be used in Production Engineering courses.

3 Researches about the use of games

The use of games as a tool to help teach specific content in the classroom is not a new idea (HILL et al., 2003). Education scholars, such as Vygotsky (1989) and Piaget (1972), present games as extremely important tools for the development of cognitive skills, especially in early childhood and elementary education. Through them, the child acts and has his/her creativity stimulated, in addition to acquiring self-confidence and concentration. These same opinions are reinforced by Macedo et al. (2008), according to whom, in addition to promoting cognitive development, "playing" is engaging, interesting and stimulating.

Even though much of the initial research was focused on early childhood and elementary school, today there is already a lot of research on the use of games in higher education. Bahadoorsingh, Dyer and Sharma (2016) states that games provide a different pedagogical perspective within a higher education context. Although they may not seem natural, they represent two critical factors that need to be considered: they are impactful and they are emerging as a potential source of disruption in current teaching models.

To be an educational game, games need to be focused on teaching a certain subject, expanding concepts and improving some skills and attitudes that players/students seek/acquire during the game (Dempsey et al., 1996). The use of games for pedagogical purposes has grown and covered several areas, from health (Alloni et al., 2017; Pires et al., 2019), resource management (Bellotti et al., 2014; Othman et al., 2016) and even learning new languages (Eltahir et al., 2021).

Several authors such as Kishimoto (2004) and McDowell et al. (2006) reinforce the importance of the game as a great motivator and facilitator so that concepts can be absorbed more quickly and dynamically. On the other hand, Bonetti (2014) reports that game development is arduous and costly, which makes it difficult for teachers to perform them, who need to resort to existing games. According to the author, there are no specific environments for searching games for educational purposes, these "are scattered on the Internet in a non-centralized way, without a systematic and uniform representation of their relevant information", which makes the search time-consuming, complicated and not very efficient.

From this difficulty arises this research, which identified and listed some games used in the teaching of Production Engineering, in order to facilitate access to games by interested parties.

4 Results: a list of games for Production Engineering

At first, more than 20 items were defined to describe the characteristics of the games found. However, the lack of standardization and information meant that only 5 items were presented here, because only these fields could be filled in, for at least 50% of the games listed.

The listed features are:

- **Name:** the game's title;
- **Description:** brief description of the game based on information provided in publications;
- **Access:** informs the type of access, whether the game can be accessed freely (free), paid or trial (free to test, but pay to use), also indicates if the game is available or if it is for internal use only /specific;
- **Format:** indicates whether the game is physical or digital;

- **Areas:** indicates the areas that are worked on by the game, such as: management, marketing, life cycle, etc.

Characteristics that can be considered important for pedagogical purposes, such as: subjects in which games are usually used, number of players/teams, time required to apply the games, etc., were not listed due to lack of information.

The reference work(s) used in the research were included in the results. Table 1 presents the games identified and applicable to the Production Engineering course.

Table 1 – List of games applied to Production Engineering and their characteristics.

Name	Description	Access	Format	Area(s)	Cited by
(not indicated - ETO SIM)	A simulation game that involves product lifecycle planning in an Engineer-To-Order (ETO) environment.	-	Digital	life cycle, LCA	Gutiérrez & Sastrón (2009)
(not indicated)	A virtual reality game in which players "visit" an industrial environment and need to identify various elements and concepts, as well as establish hypotheses and models.	-	Digital	manufacturing systems	Urigo et al. (2022)
(not indicated)	A computer simulation game between juice companies.	-	Digital	business management	Braghirolli et al. (2016)
Beer game	A board game that already has a digital version and that simulates the beer supply chain.	-	Physical and Digital	supply chain management, bullwhip	Despeisse (2019), Machado et al. (2021)
Bernard - Industrial Simulator	A business game in the consumer durables sector that reproduces operating conditions of the main functional areas of an industry. For each simulated period it is necessary to plan the machines, facilities and raw materials needed, human resources.	Paid	Digital	production, finance, marketing and logistics	Igidio et al. (2017), Ishihara, Neto & Neumann (2021)
BEWARE Game	A risk management simulation game.	-	Digital	risk management	Hauge & Riedel (2012)
Business Game	A business game used in Young Business Talents (an international competition) whose objective is to analyze, plan and control a company.	Free	Digital	production, finance, marketing and logistics	Igidio et al. (2017)
Business Management	A business game in the area of microcomputers.	Paid	Digital	production, finance, marketing and logistics	Ishihara, Neto & Neumann (2021)
Cesim Firm	A business game in the pharmaceutical industry that integrates the functional areas of production, marketing and logistics, helping participants to plan their strategies and practice decision making, having interactions between all typical functions within the company.	Paid	Digital	production, finance, marketing and logistics	Igidio et al. (2017), Ishihara, Neto & Neumann (2021)
CityCar	A dynamic simulation game related to the development of new products in which teams of 5 to 7 players compete against each other.	-	Physical	product development	Despeisse (2019), Kerga et al. (2014)
COSIGA	A simulation game focused on simultaneous engineering in which players must develop a truck (construction, mobile home or delivery).	Free	Digital	product development	Kerga et al. (2014), Hauge & Riedel (2012), Riedel, Pawar & Barsonn (2001)
Factory Heroes	A cooperative RPG-style board game that works on sustainable management in a manufacturing company.	-	Physical	sustainability	Despeisse (2019)
Fishbanks	A board game that already has a digital multiplayer version in teams that represent fishing companies and need to maximize their profits while competing for natural resources.	Paid	Physical and Digital	resource management, sustainability	Despeisse (2019)
Furniture Factory	A computer simulation game that works basic concepts of production engineering for freshmen through a scenario referring to a furniture company.	-	Digital	manufacturing systems management, Production Engineering concepts	Bengoa et al. (2013)

Name	Description	Access	Format	Area(s)	Cited by
Production Game (Game da Produção)	A mobile game developed specifically for the Production Engineering course at UnB, in which students can simulate their trajectory through the course, understanding the disciplines and activities that must be carried out until completion.	-	Digital	Education	Júnior, Simão Monteiro & Madeira Campos (2019)
General Management	A business game in the field of graphic design industry.	Paid	Digital	production, finance, marketing and logistics	Ishihara, Neto & Neumann (2021)
Production Management (Gestão da Produção 1 -GP-1)	A business game whose objective is to determine the quantity of products to be produced in normal and extended hours and how much of the production must be outsourced, so that the profit is maximum.	-	Digital	production, finance, marketing and logistics	Igidio et al. (2017)
GLOTRAN	A computer simulation game that simulates the development and production of a product across different teams.	-	Digital	product development	Kerga et al. (2014)
GSim - Goldratt Simulator	A simulator used as a game to work concepts of Theory of Constraints (TOC)	Free	Digital	production management, theory of constraints	Machado et al. (2021)
Industrial Simulator	A business game in the area of physical goods.	Paid	Digital	production, finance, marketing and logistics	Ishihara, Neto & Neumann (2021)
Industrial Strategic Simulator	A business game in the area of physical goods.	Paid	Digital	production, finance, marketing and logistics	Ishihara, Neto & Neumann (2021)
JOGAI - The Industrial Engineering Undergraduate Game	A game that simulates the supply chain of gemstones and jewelry through group dynamics, with assembly of parts in which different companies compete with each other.	-	Physical	planning and control	Barçante et al. (2011)
LCA Game	An RPG-style computer simulation game that focuses on analyzing the environmental impact of the company's coffee machine production.	-	Digital	life cycle, LCA	Despeisse (2019)
Lean Board Game	A board game that simulates the operation of an industry allowing the monitoring of various indicators.	-	Physical	production management	Machado et al. (2021)
LSSP_PCP*	A business game in which the simulated company produces three different families of meshes, with sectors of Knitwear. Dyeing and Finishing. It is necessary to manage the company that has variable demand.	Free	Digital	demand forecast	Igidio et al. (2017)
Moto Cycle	A business game in the area of motorcycle industry.	Paid	Digital	production, finance, marketing and logistics	Ishihara, Neto & Neumann (2021)
NCTB GAME	A business (computerized) game in which students must make weekly decisions related to different areas (purchasing, production, quality control and marketing) of a packaging company in order to obtain the best possible results.	Paid	Digital	production, finance, marketing and logistics	Bringelson et al. (1995)
One thousand kWh	A card game in which the highest score is sought, which is obtained by reducing the energy saved in the company's plant.	-	Physical	sustainability	Despeisse (2019)
Production Management – PM	A business game in the field of furniture industry.	Free	Digital	production, finance, marketing and logistics	Ishihara, Neto & Neumann (2021)
Production Planning Simulation – PPS	A business game in the area of fictional products.	Paid	Digital	production, finance, marketing and logistics	Ishihara, Neto & Neumann (2021)
Production System Simulation Laboratory – PSSL	A business game in the area of knitting industry.	Free	Digital	production, finance, marketing and logistics	Ishihara, Neto & Neumann (2021)
SBCE game	A dynamic simulation game in which players must develop a simplified aircraft structure respecting the established parameters, using two different proposals (PBCE and SBCE).	-	Physical	product development, lean	Kerga et al. (2014)

Name	Description	Access	Format	Area(s)	Cited by
Strategic Simulation (SDE <i>Simulação Estratégica</i>)	A business game in which participants plan and implement a new venture that will produce and market the RPB – Portable Beverage Refrigerator – a new product, without equal, competing with other simulated companies in different markets. At the end of the simulation, the performance of the groups is evaluated based on the analysis of the results obtained.	Paid	Digital	entrepreneurship	Igidio et al. (2017)
Simulators and Management Models (SDG – <i>Simuladores e modelos de gestão</i>)	An interactive business simulation applied in the Global Management Challenge (international strategy and management competition) in which each team manages a company with the objective of obtaining the best investment performance for their company in the market in which it operates.	Paid	Digital	production, finance, marketing and logistics	Igidio et al. (2017)
Shoe Maker	A business game in the shoe industry.	Paid	Digital	production, finance, marketing and logistics	Ishihara, Neto & Neumann (2021)
Simulare	A business game in which teams compete with each other, having to make decisions such as price, investment in advertising, receipt and payment terms, purchases of inputs and machinery, hiring and firing of personnel, loans, financing, etc.	Paid	Digital	production, finance, marketing and logistics	Igidio et al. (2017), Ishihara, Neto & Neumann (2021)
Production Planning Simulation (SPP <i>Simulação de Planejamento da Produção</i>)	A business game in which participants act as leaders of an industrial unit, that produces VERIPEX (fictitious product), which must be shipped according to the quantity requested by the customer. Participants must make strategic and managerial production decisions, simulating results, in quarterly cycles. Who accumulates the highest net profit at the end of the 4th period wins the game.	Paid	Digital	production, finance, marketing and logistics	Igidio et al. (2017)
Supply Chain and Channel Management	A business game in the area of microcomputers.	Paid	Digital	production, finance, marketing and logistics	Ishihara, Neto & Neumann (2021)
TFC business game (The Fresh Connection)	A computer simulation of a supply chain that must be optimized.	-	Digital	simulation, operational research, production, quality, logistics	Mosia (2018)
The Product Line Planning Game	A game in the form of dynamics that brings consumers and developers together by facilitating the presentation of consumer requirements and feedback to developers. As a result of the matches are scenarios/stories that help in the development of projects.	-	Physical	agile method	Carbon et al. (2008)
The Trimrian Factory Game	A dynamic simulation game that depicts a bankrupt company trying to get back on its feet by fulfilling a customer's orders within 6 rounds.	-	Physical	production	Jensen (2008)
Topaz Management Simulation	A business game with 3 different product options.	Paid	Digital	production, finance, marketing and logistics	Ishihara, Neto & Neumann (2021)
Virtonimics Enterprenuer	A business game in the clothing field.	Paid	Digital	production, finance, marketing and logistics	Ishihara, Neto & Neumann (2021)
Virtual Business Retailing	A business game in the grocery/convenience store area.	Paid	Digital	production, finance, marketing and logistics	Ishihara, Neto & Neumann (2021)

Source: Authors (2022)

Even performing a very limited search, it could be noted that part of the publications found in the research were not aligned with the scope of this work. Among them is the article by Zhou (2018) that analyses the scenario of the chemical industry through game theory. Another article that was discarded, although it presented an analysis of publications in the area of games for Production Engineering, was that of Rosado and

de Souza (2021), since the authors carried out a bibliographic mapping, without it being possible to identify any game.

Contrary to Rosado and de Souza (2018) are the works of Despeisse (2018), Igidio et al. (2017), Ishihara, Netto and Neumann (2021) and Kerga et al. (2014) which present game relationships with different approaches. Despeisse (2018) analyses 6 (six) games and relates them to the cognitive development domains of Bloom's Taxonomy. Igidio et al. (2017) succinctly present 8 (eight) business games and an applied study of the Management of Production 1 (GP-1), Ishihara, Netto and Neumann (2021) present 16 business games from the analysis of their manuals, bringing information internals of the games and Kerga et al. (2014) cites three games related to product development and analyses and presents the results of applying another game in the area. The games that were only mentioned by these authors are listed in this research, although they have little general information.

The scarcity of information caused the work of Scholl, Gube and Koppatz (2021) to be disregarded, since the authors report the development of two physical games (Social Engineering Theater and Risk Roulette) that could not be properly tested due to the Covid-19 pandemic.

5 Conclusion

This research aimed to present a list of games that can be used in Production Engineering teaching, making the teaching-learning process more motivating and effective. As a result, 44 games were found and listed.

There was a lack of standardization in the obtained data. which makes it difficult to properly and quickly evaluate and access the games. The absence of information on locations and access methods also prevents verifying whether the games are really active. This lack of information implies the need to seek new materials so that there is better detail and more direct guidance to readers who are interested in making use of games in their classes.

This research emerged as part of a larger research which aims to establish a methodology for identifying and making available information of games that facilitate their discovery and application by teachers and other interested parties. In general, the lack of standardized information that describes games as a learning object is something that has been studied, with researches related to the adoption of metadata standards, such as the Learning Object Metadata (from the IEEE) and the Dublin Core (DC). This adoption becomes necessary so that works like this can be more meaningful, bringing more relevant and updatable information.

As future research, a deeper analysis of the identified games is suggested in order to update the information and present only games that are active and accessible (free of charge or for a fee) to the public, since it is believed that a good part of the games listed here are not available or are already obsolete, as in the case of The Product Line Planning Game (Carbon et al. 2008) which either must have undergone an update, or has already left the market, since it used floppy disks.

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Evaluation of the effectiveness of the use of games in the teaching of Production Engineering: an experiment with Goldratt Simulator

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Abstract

Traditional and theoretical classes are usually tiring and their contents are poorly absorbed. One way to apply and fix the contents in a more attractive and motivating way is through the use of active methodologies, whose use has been encouraged by the new curricular guidelines of engineering courses in Brazil. Game-based learning (GBL) is one of such approach. Although many games are already used in classroom environments, e.g. Beer Game, Lean Board Game and Goldratt Simulator, there is still a lack of studies on the effectiveness of its application. In 2020, a study about the use of games in Production Engineering courses was initiated, which resulted in the development of questionnaires and the suggestion of a methodology for evaluating the effectiveness of the use of GBL. In order to identify the effectiveness of the use of Goldratt Simulator, as a game, in the learning process this evaluation methodology was applied during an experiment carried out in the discipline of Production Management IV, in which two groups were defined (control and experimental). After the classes and the application of the questionnaires, it became evident: greater engagement and confidence by the experimental group and greater fixation of concepts by the control group. Furthermore, the evaluative tools proved to be adequate to give feedback to the teacher, presenting themselves as an important diagnostic tool.

Keywords: Learning evaluation methodology; GBL; Educational games; Production engineering.

1 Introduction

Changes in student profiles, who think that theoretical and traditional classes are usually tiring and demotivating, have led to new teaching methodologies being developed and applied (Rubeus, 2021).

The use of such methodologies has even been encouraged by teaching guidelines, which suggest that active methodologies (in which students become protagonists in the learning process) are constantly used (MEC, 2019).

One of the methodologies that promises to stimulate student development is Game Based Learning (GBL), which uses analogue or digital games in classrooms (Karagioras & Niemann, 2017). The methodology is mainly used to generate greater engagement, motivate action, promote learning and solve problems in a creative way (Lester, 2014). It is an excellent way to help students lose resistance in the face of complex topics (Sales et al., 2017).

There are several studies that present the creation of game-based learning environments for a wide range of curricula (Warren et al., 2008; Kebritchi & Hirumi, 2010). In the university where this project has been developed, some analogue games are already used, such as Beer Game and Lean Board Game, and virtual simulators, such as Goldratt Simulator, to support the Production Management disciplines of the Production Engineering course. It so happens that, so far, in the course in question, this methodology has been applied without carrying out a scientific evaluation of the benefits of its use.

According to Lester (2014), research on game-based learning has matured and today there are empirical studies that qualitatively demonstrate students' learning gains when interacting with educational games in a variety of subjects, however, these studies often make use of non-standard instruments. Furthermore, quantitative research is more difficult to identify.

In 2021 a research developed by the authors resulted in the elaboration of a set of tools (questionnaire to characterise the participants and three instruments evaluation) that allow to analyse the perception of students and the level of learning obtained by the use of games in the learning process (Machado et al., 2021). During

the same period, the Goldratt Simulator was used as a game in the discipline of Production Management IV, offered to a 4th year class at a Brazilian public university. Due to the importance of analysing the effectiveness of its application, the authors of this research used the tools previously developed in an attempt to answer the following question: is the use of Goldratt Simulator effective for greater student motivation and learning?

In order to verify the effectiveness of the use of the Goldratt Simulator as a motivation and learning tool, a research was conducted applying the tools previously developed. The instruments and results are presented in this work.

2 Methods

After carrying out a systematic review to identify instruments for evaluating the effectiveness of the use of games in teaching, the results of which were published by Machado et al. (2021), an action research was carried out regarding the application of a game already consolidated and commonly applied in the discipline of Production Management IV of the course studied, which uses the Goldratt Simulator, a simulator of the production process, which allows the player to identify and deal with problems that can occur in real situations and that allows the learning of several concepts of Theory of Constraints, an important content for the Production Engineering course.

According to Oquisit (1978, apud Mello et al, 2012), action research can be defined as the production of knowledge guided by practice, occurring simultaneously to the modification of a reality that is also part of the research process. Thiollent (2007, apud Mello et al, 2012) emphasises that for a research to be considered an action research, it is essential that there is an action on the part of the people involved in the problem under observation, that this action is non-trivial to the point of needing to investigation and that researchers play an active role in conducting, monitoring and evaluating the research. It is added that this method is appropriate when the research question is used to clarify how an action of a person can improve the functioning of the system and how this process will take place, thus aiming to learn from it (Coghlan & Brannick, 2008). apud Mello et al, 2012).

Thus, an experiment was carried out in the discipline of Production Management IV of the Production Engineering course of a Brazilian public institution. In this experiment, the class was divided into two groups, one group was exposed to a theoretical-expository teaching-learning process, while the other used an approach along the lines of GBL (Game-based learning). With the purpose of measuring the effectiveness of each approach, the students of each group were questioned using the evaluation tools developed from the bibliographic research.

At this stage, of the 32 students in the class, 15 volunteered to participate in the research, the participants were divided between the control (9 students) and experimental (6 students) groups in order to maintain a certain homogeneity in relation to the average of ages and gender. However, right at the beginning of the questionnaires, 5 students in the control group dropped out, leaving 10 participants.

3 Evaluation methodologies

In view of the existence of few validation studies on the effectiveness of the use of games in teaching, the authors of this work carried out, between the years 2020 and 2021, a research whose result was the elaboration of a questionnaire to characterise the participants and three instruments evaluation, one of perception, another of self-evaluation and a third of learning. These three instruments were published in the proceedings of PAEE/ALE'2021 under the title "Game-based learning in a Production Engineering course in Brazil." by Machado et al. (2021) and are the basis of this research, since they were used to measure the effects of applying the Goldratt Simulator in the discipline of Production Management IV. The instruments created and used throughout this new research are presented below.

3.1 Participant's characterization questionnaire

The participants' characterization questionnaire begins with the student's acceptance to participate in the experiment and is applied through "Google Forms". The questionnaire comprises the following questions:

Gender: () Female () Male () Not informed
Age: _____
What is your level of knowledge about Theory of Constraints (TOC)?
 () I've never heard of it, I don't know what it is
 () I've heard of it, but I don't know what it is
 () I've heard of it and I know it's related to production systems
 () I have read and / or attended classes on the subject
 () I know and am able to discuss the matter properly
Based on the teaching plan presented for the subject, analyse the following statements using the Likert scale from 1 (strongly disagree) to 5 (strongly agree):
 I believe that subject is important for my training
 I would enrol in the course if it was not mandatory
 I think the proposed assessment is fair
 I think the proposed assessment is challenging
 I think the proposed methodology looks interesting

* Main concept subject to be worked on in the experiment

Figure 1. Specific participant's characterization questionnaire

Source: Machado et al (2021)

This questionnaire must be applied at the beginning of the classes, before the first instructions on the content are offered, so that the groups can be properly organised.

3.2 Perception questionnaire

Perception analyses reach the first two levels proposed by Kirkpatrick (reaction and learning). The first analysis will begin with the application of a perception questionnaire combined with the Flow Theory.

Using the Likert scale from 1 (strongly disagree) to 5 (strongly agree), students from both groups should answer the following questions:

Absorption / Immersion:
 1. During the activity I lost track of time
 2. During the activity, I felt totally immersed
 3. The activity made me excited
 4. The activity made me feel self-confident
 5. The activity stimulated my interest
 6. The activity piqued my curiosity

Pleasure:
 7. The activity gave me a good feeling
 8. I had fun during the activity
 9. The activity brought me joy
 10. The activity was pleasant

Motivation:
 11. This type of activity should be carried out more frequently
 12. This is an activity that I willingly performed
 13. This is an activity that I would participate in even if it was not linked to the presence
 14. This is an activity that I would participate in even if it was not linked to the note
 15. This is an activity that I would do even though I didn't receive anything in return

Skills:
 16. This activity improved my critical thinking
 17. This activity improved my problem-solving ability
 18. This activity improved my analytical ability
 19. This activity improved my ability to manage time and resources
 20. Some problems became clear with this activity

Figure 2. A generic developed perception questionnaire

Source: Machado et al (2021)

3.3 Post-test

After conducting the experiment, the following questionnaire must be applied to students in both groups. For a coherent evaluation it is fundamental that the questions are neutral, that is, they are not directly related to the game. We understand that the ideal would be the realisation of conceptual questions that could be analysed in a practical way, for example by a TRUE or FALSE model.

Mark the sentences below with TRUE or FALSE:

1. The Theory of Constraints (TOC) argues that companies have many constraints that make it difficult to reach their goal
2. The Theory of Constraints (TOC) states that local optima result in global optima
3. Capacity constrained resources (RRC) are resources that, if poorly managed, can become bottlenecks
4. Bottlenecks impede demands from being fully met
5. Bottlenecks and RRCs are synonymous
6. The buffer is the stock of materials in process that must be present throughout the entire production line
7. The Rope is the sequencing of material release to the factory based on the discounted Lung Drum
8. The production schedule of the Bottleneck is the Drum and it is from there that the rest of the factory must be subordinated
9. An hour lost on a non-bottleneck resource is an hour lost on the entire system
10. An hour saved on a non-bottleneck resource is an hour gained system-wide
11. In the classic Drum-Lung-Rope method, in-process buffers are dimensioned and controlled in the form of time
12. Non-bottleneck resources should adjust their production speeds to the Drum

Figure 3. The post-test with specific questions about Theory of Constraints

Source: Adapted from Machado et al (2021)

3.4 Self-assessment questionnaire

As a last tool, a self-assessment is suggested. In this, students will have the chance to review the contents worked and analyse their own level of understanding.

Analyse your level of understanding by checking 1 (I didn't understand) to 5 (I fully understood).

1. The Theory of Constraints (TOC) argues that companies have very FEW constraints that limit the achievement of the goal
2. The Theory of Constraints (TOC) states that local optima DO NOT result in global optima
3. Capacity constrained resources (RRC) are resources that, if poorly managed, can become bottlenecks
4. Bottlenecks impede demands from being fully met
5. Bottlenecks and RRCs are NOT synonymous
6. Time buffers are reflected in physical inventories located at strategic points to protect system constraints
7. The Rope is the sequencing of material release to the factory based on the Drum discounted the Buffer
8. The production schedule of the Bottleneck is the Drum and it is from there that the rest of the factory must be subordinated
9. An hour lost on a NON-bottleneck resource is NOT a system-wide lost hour, but an hour lost on the bottleneck resource is a system-wide lost hour
10. An hour saved on a NON-bottleneck resource is NOT an hour gained system-wide.
11. In the classic Drum-Buffer-Rope method, in-process buffers are dimensioned and controlled in the form of time
12. Non-bottleneck resources must NOT adjust their production speeds to the Drum. They must operate according to roadrunner logic

Figure 4. The self-assessment with specific affirmatives about Theory of Constraints

Source: Adapted from Machado et al (2021)

4 Results

As for the application of the Goldratt Simulator, the 10 students who participated answered the questionnaires to characterize the participants and the perception and learning assessment questionnaires, but only 9 responded to the self-assessment.

4.1 Participant's characterization questionnaire

Regarding gender, 5 men and 5 women participated in the experiment. The average age is 22.8 years old, with a maximum age of 27 and a minimum age of 21. Regarding the level of knowledge of the Theory of Constraints, all 10 participants already knew something about the subject. For questions related to expectations of the topic discussed in the course, the means and deviations were presented in Table 1.

Table 1: Assessment of participants' expectations

	Average	σ
I believe that this subject is important for my training	4.8	0.6
I would enrol in the course if it was not mandatory	4.0	1.1
I think the proposed assessment is fair	4.4	0.7
I think the proposed assessment is challenging	4.3	0.7
I think the proposed methodology looks interesting	4.4	0.8

Source: authors (2021)

4.2 Perception questionnaire

In the perception assessment, composed of 20 questions whose answers were based on a Likert scale from 1 (strongly disagree) to 5 (strongly agree), the means and deviations between the control and experimental groups were calculated and are shown in Tables 2, 3, 4 and 5.

Table 2: Participants' perception of Absorption / Immersion

	Control Group		Experimental Group	
	Average	σ	Average	σ
Q1. During the activity I lost track of time	1.8	0.5	4.2	0.4
Q2. During the activity, I felt totally immersed	2.8	1.5	4.5	0.5
Q3. The activity made me excited	2.8	1.5	3.7	0.8
Q4. The activity made me feel self-confident	3.3	1.5	4.5	0.5
Q5. The activity stimulated my interest	3.8	1.5	4.8	0.4
Q6. The activity piqued my curiosity	3.8	1.5	4.8	0.4

Source: authors (2021)

Regarding immersion, it was noted that the experimental group felt more immersed and motivated, presenting higher averages and smaller deviations. Attention to the first item, that refers to the loss of the notion of time, whose difference between the groups is quite significant, corroborating the idea that traditional classes are more tiring. This statement is also confirmed by the report of one of the participants:

"As a member of the control group, I believe it is worth highlighting the teacher's didactic ability. In the content presented, the examples used, clarity in speech and attention to students' doubts count a lot for a very positive evaluation of the activity taught. Without these highlighted points, due to the relatively long class time (4h), I don't think I would feel involved and excited to make the most of it. As classes are usually long, they can become tiring and even though there is a good effort from the teacher and an effort on the part of the students, even so, with only theoretical classes it is more difficult to maintain concentration at all times and lose this notion. of time. By adding a more dynamic activity, students are more involved and time goes faster".

Table 3: Participants' perception of Pleasure

	Control Group		Experimental Group	
	Average	σ	Average	σ
Q7. The activity gave me a good feeling	3.8	1.5	4.5	0.8
Q8. I had fun during the activity	2.8	1.0	4.8	0.4
Q9. The activity brought me joy	2.8	1.0	4.0	1.1
Q10. The activity was pleasant	3.3	1.5	4.5	0.5

Source: authors (2021)

For pleasure, the experimental group also presented higher ratings, with attention to item Q9 in which the deviation of the experimental group exceeded the control group, even though the average is higher.

Table 4: Participants' perception of Motivation

	Control Group		Experimental Group	
	Average	σ	Average	σ
Q11. This type of activity should be carried out more frequently	3.3	1.0	4.8	0.4
Q12. This is an activity that I willingly performed	4.0	1.4	4.8	0.4
Q13. This is an activity that I would participate in even if it was not linked to the presence	3.8	1.5	4.3	0.8
Q14. This is an activity that I would participate in even if it was not linked to the note	3.8	1.5	4.5	0.8
Q15. This is an activity that I would do even though I didn't receive anything in return	3.8	1.5	4.3	0.8

Source: authors (2021)

As for motivation, again, the experimental group showed higher ratings, with lower deviations than the control group.

Table 5: Participants' perception of improved Skills

	Control Group		Experimental Group	
	Average	σ	Average	σ
Q16. This activity improved my critical thinking	3.8	1.5	4.8	0.4
Q17. This activity improved my problem-solving ability	3.5	1.3	4.5	0.5
Q18. This activity improved my analytical ability	3.5	1.3	4.5	0.8
Q19. This activity improved my ability to manage time and resources	3.0	1.4	4.5	0.5
Q20. Some problems became clear with this activity	2.5	1.3	4.8	0.4

Source: authors (2021)

Regarding skills, the control group presented lower averages with always higher deviations than the experimental group.

Thus, it can be seen that the experimental group has a higher average for all questions. This shows that, in general, the group that used the game became more immersed, had more pleasure in performing the activity, felt more motivated and believed to have improved their skills.

4.3 Post-test

For the second instrument, the learning assessment, made up of 12 True/False questions, a different result was obtained than expected. The control group had a higher average of correct answers than the experimental group, as shown in Table 6. This can be explained by reasons such as incorrect division of groups, greater ease on the part of students who belonged to the control group or lack of attention to answer the questionnaire. A new application, with a larger sample of people, may indicate a different average, since the sample was composed of the most engaged students in the class.

Another factor that may have been a complicating factor for the learning of the experimental group is that the interest in simulating the activity and the fact that the students were in environments different from the teacher (since the classes were held remotely due to the pandemic) prevented the better control of the teacher and allowed the students to simulate while the teacher performed the explanations, which are of paramount importance for obtaining the concepts presented.

Table 6: Average of correct answers in the learning evaluation form by group

Group	Average
Control Group	9.25
Experimental Group	8.00

Source: authors (2021)

A feedback was received on this form:

I found the insights obtained by using the game helped me a lot to understand. Anyway, I think the 4 hours were a bit exhausting and may have hampered learning.

This report brings a reflection: even though the use of the game makes the class "lighter", as observed by the first evaluation instrument, time is still a critical point.

It is also worth mentioning that questions 1, 6 and 12 were the ones with the highest frequency of errors, with only 4, 4 and 2 correct answers respectively.

4.4 Self-assessment questionnaire

The self-assessment added to the results of the learning assessment (post-test) serves as a parameter for the teacher to identify the points of difficulty for students to understand. Thus, following the Likert scale pattern 1 (I did not understand at all) to 5 (I fully understood), the following averages were obtained for the established statements (Table 7).

Table 7: Average of self-assessment questions per group.

Group	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Total
Control Group	3.75	3.5	4.75	4	4,5	5	4.5	3.75	5	4.75	5	3.75	4.35
Experimental Group	3.6	4.8	4.6	4.8	4.2	4	4.6	4.8	4.4	4.2	4.4	4	4.37

Source: authors (2021).

In general, a high level of confidence and security in the answers by all students can be observed. An interesting detail is that the lowest averages of the experimental group are really related to the questions whose students had greater assimilation difficulties (1, 6 and 12), according to the number of errors in the learning assessment.

5 Conclusion

Following the idea defended by McGonigall (2011 apud Moores, 2016) that participation in games should be voluntary, participation in the experiment was optional, which implied a low adherence of students. The

exceptions refer to students who normally interact more with the teacher and are more willing to participate in classes. The division of experimental and control groups in an entire room could indicate other results, especially in the learning assessment instrument. It is also necessary to think that in this freedom of participation, those who chose not to take part in the research, even because they had never used a game as a teaching tool, may have missed the opportunity to discover a new method in which they could enjoy more, have identification with and ease to learn.

The perception assessment instrument showed an acceptance of the use of games, as well as greater immersion, pleasure, motivation and skills improvement perception on the part of those who participated. It also indicated greater development of important and expected skills of a production engineer. Participants were very interested in the proposal to use these means as a form of teaching. The students did not present technical difficulties to answer the questionnaires. The use of games and simple assessment tools, such as those developed in this study, are alternatives to measure student performance and perceive difficult points, without having the pressure of a test, in addition to returning the results more quickly to students.

The learning assessment brought attention for pointing out a different result than expected. Students who did not use the simulator performed better, even though they had less confidence in their answers, as indicated by the self-assessment form. It is important that there are new applications with a greater number of students to verify if the results are maintained in this proportion.

In order to answer the question of this work, by a perception way, the use of the game brings more immersion, pleasure, motivation and skills improvement. Although, in the learning field, the result has shown to be inferior to those who used the game. This may be due to the fact that the application was carried out online (not face-to-face), with the teacher not having control over the students regarding the fact that they stopped using the simulator so that they could focus attention on the explanations, which were essential for the correct absorption of the concepts that were collected during the post-test. The results presented by the post-test and the self-assessment questionnaire were quite consistent and corroborate the evidence of the quality of the instruments used.

For future research, the application with a larger number of participants is indicated and the need to investigate the low adherence of students to the research is evidenced, since a lack of time for extra activities was justified, even when the application was made during the class schedule and questionnaires take very few minutes to be answered. It is also worth mentioning the opportunity to apply the assessment instruments to other subjects and even other teaching areas, with the necessary adaptations.

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Multidisciplinary projects for Engineering, Business Administration and Design programs: Construction and mapping of common skills through an analysis instrument

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Abstract

In Brazil the Engineering, Business Administration and Design courses have, each one of them, a list of own competences, or skills, that are established on the curricular guidelines by Ministry of Education, to be developed by students along the course. This is not a closed list, and specific competences attending specific courses demands can be included, in order to training students with innovative and current profile. The engineering courses guidelines point out that students need to be trained with active learning strategies putting them as protagonists of their training and, besides this, courses need to make use of projects to develop the soft skills desirable in this training. To achieve an integrative approach, an institution created a new curriculum in which the students of these three courses interact in multidisciplinary projects. This approach has with bases the innovation tripod supporting the collaboration of the students of these three courses, aiming training them to a global scenario that claims professional's broad vision. Each multidisciplinary project is developed in an academic semester and the students need to enrol in two projects per semester. In this context emerged the need of a convergent list of competences that translate the competences of these three courses, without lose the essence of each one. This paper presents the process of building this unique list of competences, for training professionals with an updated and innovative profile. From this, a survey was carried out to gather information on the competences developed in these projects. The research method was the documental analysis for the creation of the list of competences. To survey the competences that are offered in the projects, a questionnaire sent to the instructors was used. The list of competences allowed the creation of an activity plan, in which they declare the competences that will be developed by students, ensuring the management of the learning process.

Keywords: Problem Based Learning; Competences; Multidisciplinary projects; Innovation tripod; Soft skills.

1 Introduction

The Engineering, Design and Business Administration courses at a higher education institution in Brazil have in common the use of projects that are offered to students throughout the course and in parallel to the subjects in the curriculum. These projects are "packaged" in a discipline called PAE (*Projetos e Atividades Especiais*, in English, Special Projects and Activities) and thus meet the need to be placed as elements of the curriculum. In this discipline, a list of more than two hundred projects is offered to the students, who have to choose at least two in each academic semester (Mattasoglio Neto et al, 2019).

The focus of this paper is the competencies that these projects allow be developed by the students. These projects need to meet two different aims: strictly speaking, the projects must develop technical and transversal competences. At the same time the competencies developed must be aligned with those defined in the DCNs (*Diretrizes Curriculares Nacionais*, in English, National Curriculum Guidelines) for these courses, Engineering, Business, and Design, promulgated by the Ministry of Education (MEC, 2019), which are the courses in which these projects are developed.

The projects offered to the students have another important characteristic. The students from all three courses can enroll in any project, that is, there will be students with different profiles working together in the same project.

The question discussed in this work is: How can we identify and define the competencies that will be developed in each project whether at the same group, there are students from three different courses, with different profiles and who should develop specific competencies determined by the National Curriculum Guidelines of the Ministry of Education.

This work analyzes and compares the competences explored Engineering, Business and Design areas (MEC, 2004; MEC 2019; MEC 2020), investigating what is common and what is specific for each of these programs, seeking to arrive in a set of competences that are common to these diverse areas of activity. The importance of the study lies in the fact that entering the job market has become more demanding by the students, both because the technical knowledge as for more professional attitudes that are being achieved in the curricula at the start of the 21st century (MESQUITA et al, 2013).

To achieve this end, document analysis was used to compare the DCNs in order to identify which competences and areas require more exploration, verifying which competences are most demanded in these careers, seeking to promote the education of a professional with a profile with a broad vision that guarantees the solution of problems effectively and efficiently, mobilizing knowledge and abilities with an entrepreneurial and innovative professional attitude. In turn, it is desirable that the competences are aligned with the ONU's sustainable development objectives that are translated into the Grand Challenges Scholar Program (GCSP) (BOTELHO et al, 2020).

This nexialist vision (CHINALLI, 2013; SOUZA Jr, 2019a) focuses on the training of a professional with the ability to connect different types of knowledge, in a current context in which there is a rapid expansion of technologies in an interdisciplinary way, promoting new learning. In short, it is the professional capable of promoting the connection of the problem to the knowledge of several areas, ensuring its solution, that is, giving it nexus.

Nexialists are professionals who manage to make these "different" connections naturally, coherently organizing the relationships between different types of knowledge. Therefore, they differ from the general brain pattern of knowledge construction, they think "out of the box" as they say. They see connections where others do not, see the opposite, escape the linear thinking of the absolute majority of professionals and think in a systemic way (CHINALLI, 2013).

2 Methodology

The research method used in this work is a document analysis of the DCNs of the three courses. So, the competences of the engineering, business and design degrees were analyzed and compared. Based on this process, it was possible to generate a single framework as a result of this work. In addition, the transversal competences that could best be associated with these three areas were also sought from other sources, establishing a new set of common competences.

2.1 Study context

In the institution where the research was conducted, the "Innovation Tripod" (Souza Jr., 2019b), is used as a reference, for the connection between the knowledge of the Business, Design and Engineering areas (Figure 1). Aiming to explore this concept, the institution has the PAEs (Special Projects and Activities) as a tool to develop new competencies - both technical and transversal.

Figure 1 - Tripod of innovation at IMT (Souza Jr, 2019b)



The Figure 1 is about the union between these three courses, so that what is learned in one area can be used in the other two, for example, the business administration area that makes the products more viable for the consumption of a target audience (Viability), the design that can make this product aesthetically beautiful and functional (Desirability), and engineering that deals with the components and operation of the product (Feasibility). In general terms, the idea is to distribute these three great concepts so that, for example, an engineer also knows something related to design.

This structuring of the course with the introduction of PAEs provides an opportunity for interaction with current professionals working in the labor market, further increasing the richness of these experiences. It is worth pointing out that any professional from the Brazilian or foreign market can propose a PAEs, which, if there are students interested, can be offered and incorporated into the student's curriculum.

Based on the importance of these projects and on the needs and opportunities for the student's education, the projects can contribute to, by developing the desired competencies, generating an enrichment of the education, always based on the DCNs of the courses that guide the curricular planning of a discipline.

2.2 Data collection and analysis

The research developed had a few phases:

1st Step:

In this step, the focus was on the competences stated in the National Curriculum Guidelines for the three degree programs, Engineering, Business and Design. The method used in this work was document analysis in order to identify the competences that are intended to be developed in these degree programs. The competences of the three programs were compared in order to find similarities and differences between them. This comparison led to a single list that would cover all three degrees simultaneously.

2nd Step:

With the list of common competences, a survey instrument was designed, more precisely a questionnaire with the aim of identifying which competences would be declared in the projects offered in the PAEs in the first semester of 2022. This questionnaire was built and validated and structured in Google Forms, in order to facilitate data collection for the research that was to be developed.

3rd Step:

This step consisted of registering the projects that would be offered to students in the first semester of 2022. Each teacher or external professional who intended to offer a workshop or project as an PAE would have to fill out a form in Google forms, in which they would indicate what competencies they would develop for the students. The teachers need to detail some characteristics of the project for the registration of the activity, we

decided to make this registration online through a form and we took the opportunity to ask about the competences, in other words, they were required to answer the questions desired by the authors for the registration of the project, although other questions will be asked, the main focus will be on the competencies part, the vast majority were for the registration of the activity itself.

Once these three steps were completed, the data from step 3 was synthesized in an Excel spreadsheet, which allowed for its analysis.

3 Results and Discussion

3.1 Development

In practical terms, was separated and analyzed the eight DCNs for Engineering. Subsequently, the DCNs for Business and then the DCNs for Design were together analyzed again. The initial idea was to create a common list of 8 competences based on the Engineering DCNs, but one detail led to the appearance of more categories of competences: an engineering competence did not always have a corresponding one for other courses, or vice versa. This meant that some items in the common competency block had no connection to the 3 courses in the DCNs. However, because some of them are related in a practical way, they are in the Common Competencies block. The result was a single block with 10 competencies.

The transversal competences is a common block of 10 competences was also arrived at for the transversal competences, which were taken from some work in the area of Engineering Education (MESQUITA et al, 2013, MATTA, et al, 2018).

Summarizing, the technical competences and the transversal competences were indicated in the list of competences for the graduation programs.

3.2 The competences list

The list of competences considered for the questionnaire is:

Transversal Competences:

- **Critical Sense (Be Critical)** - The idea is for the student to have a notion of what is tolerable or not even before solving an exercise or problem, for example. This means that the student will have a dexterity to solve challenges in a certain area of knowledge, in addition to knowing whether the values and answers found are acceptable and correct.
- **Information Selection (Be Selective)** - To solve a project, an assignment, or something else, one often needs to consult sources for help, be it the teacher, recommended books, or the subject matter itself and this competence is responsible for selecting this information.
- **Knowing how to face challenges** - When it comes to real world problems, it is important that the professional knows how to face these problems, it is important that the individual is courageous and has solution attitudes, in some circumstances, it is necessary that the student has a solid opinion, a solution and has the courage to introduce it to his environment.
- **Proactivity (Initiative)** - It is the ability to anticipate and responsibly target attitudes on imposed occasions before they even happen.
- **Create / Innovate** - The ability to create products, assets, services (among others) in an innovative and creative way, that is, to produce something useful, necessary, and new.
- **Organization / Planning** - Produce and act in an organized and planned way.
- **Interpersonal relationship** - Being empathetic and agreeable, that is, thinking of others working together, acting fully, and making decisions thinking of the whole.
- **Ability to deal with the unforeseen / Working in uncertain environments** - The student's ability to deal with problems rationally and calmly, to adapt to change, to withstand various pressures imposed by the environment, and to overcome obstacles, basically resilience.
- **Ability to solve problems** - Be effective at solving problems.
- **Make decisions** - Be decisive and take harsh and determined attitudes.

Technical Competences:

- To formulate and design desirable and innovative solutions in your area.
- To analyze and understand the phenomena, events and models in your area based on the sciences that underlie it.
- Creatively conceive, design and analyze systems, products (goods and services), components or processes, technically and economically viable.
- Implement, oversee and control solutions in your area.
- Communicate effectively in written, oral and graphic forms, including communication in LIBRAS.
- Working and leading multidisciplinary teams
- Know and ethically apply the legislation and normative acts within the scope of the exercise of the profession.
- Learn autonomously and deal with new and/or complex situations and contexts.
- Understand the potential of technologies and apply them in solving problems and taking advantage of opportunities.
- Get to know the productive sector of your specialization, revealing a solid sectorial view, related to the market, materials, production processes and technologies.

3.3 Survey Development

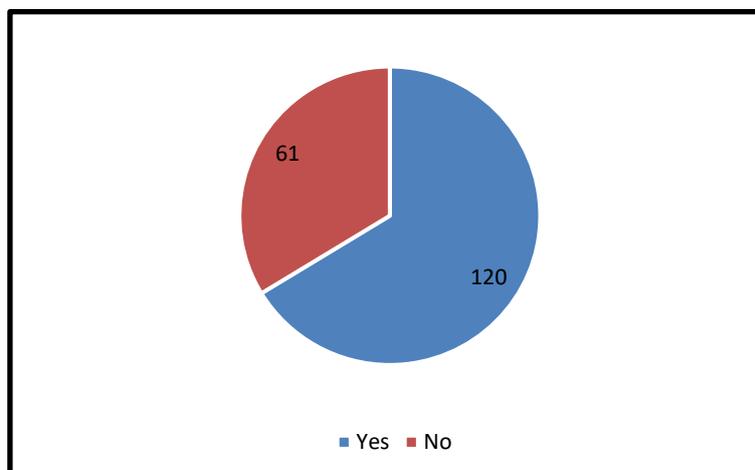
A questionnaire was created with a list of competencies, as well as other data used in the internal record of the projects themselves. The importance of having this questionnaire is the easy access to the data and its analysis in digital form.

Among the questions presented were "Has this PAE been offered sometime?", to give us control over which ones had already been offered during and before the pandemic, "Choose your PAE category", giving the person answering a list, making them choose among several areas, and the questions referring to the competencies, where we put the two lists, each one as a question, and asked the teachers to choose a maximum of 3, in the case of the transversal competencies, the respondent could choose none, but this was not the case with any of the answers. In the technical competences analyzed, it was mandatory to choose at least one competence.

3.4 The questionnaire results

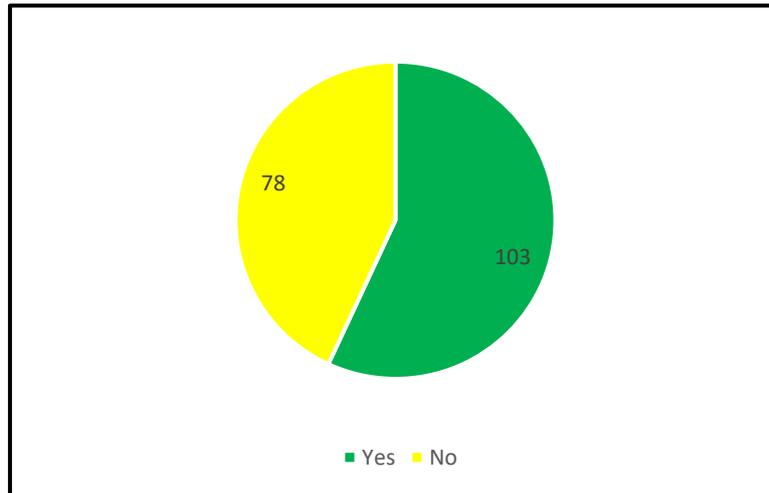
The data from the questionnaire are presented in the following.

Figure 2 - Has this project already been offered?



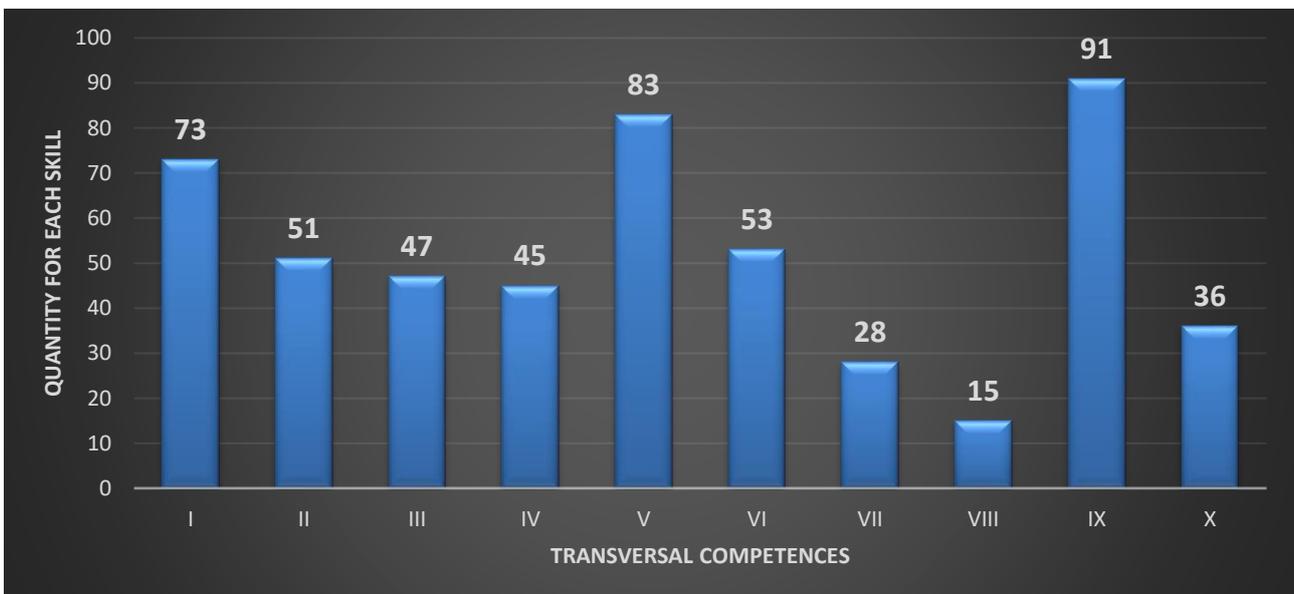
It is worth noting that PAEs have existed at Mauá since 2015, and even after almost 7 years, there is always a high demand for new PAEs, which is the case as more than 30% of these activities offered are new this semester. This provides current and ever-renewing learning

Figure 3 - Are you already an instructor at IMT?



Some PAEs instructors are professionals in the job market, and they do not work as teachers in the institution. Therefore, we asked them about their origin, and we can see in Figure 3 - Are you already an instructor at IMT? that almost 43% of the instructors who apply the PAEs are not professors, that is, they are professionals in the job market. This is an interesting fact, as it creates an experience and a new window of opportunity with even more qualified teachers.

Figure 4 - Transversal competences analyzed



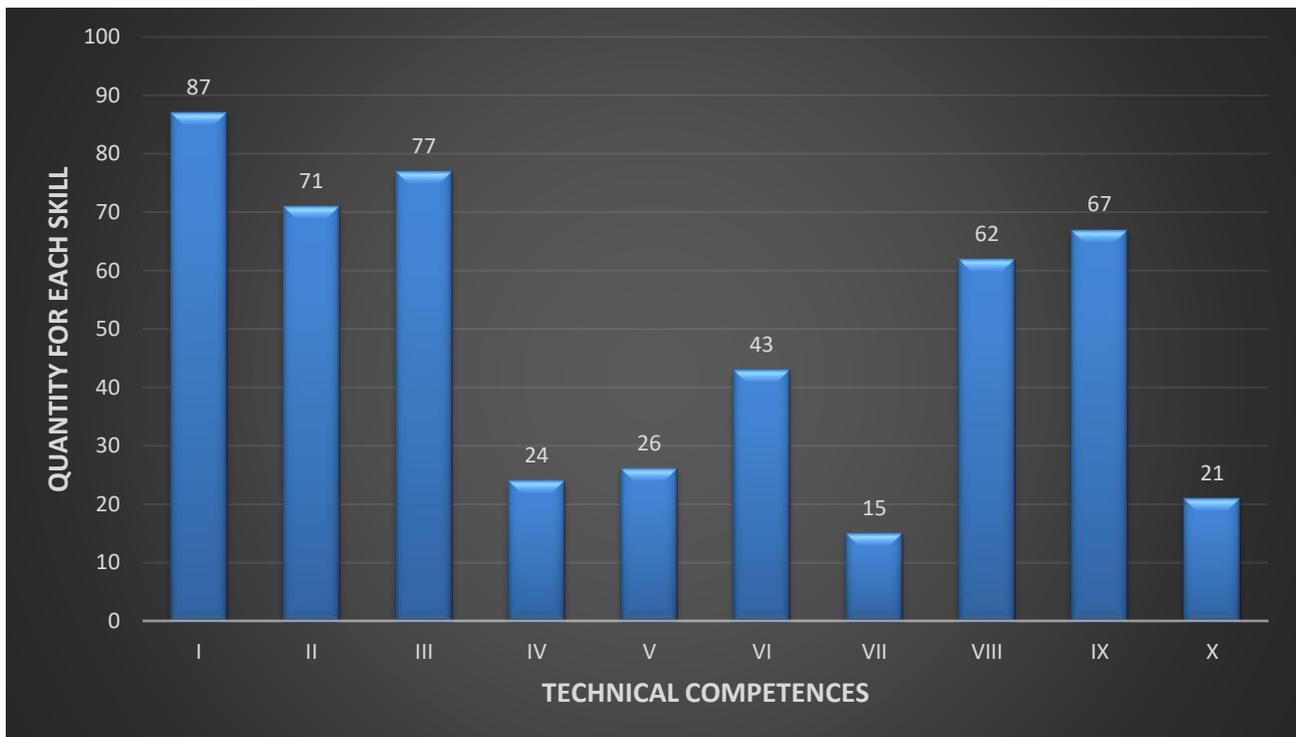
Label:

- 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 - Take decisions

It can be seen that among the transversal competences analysed, those that stood out most were those related to problem-solving competences, which shows that the projects always have a "hands-on" idea, in other words, being able to solve real-world problems. Next is the competence to create and innovate, which was also expected to receive a high number of responses, since most projects have the idea of creating a professional with new and effective resolutions. In general, it is possible to see that all competencies were met to some extent, most of the questionnaires had 3 competencies, and in this question it was not even required to select an item. With this data, we can see that this list of transversal competencies was satisfied.

Figure 5 - Technical competences analyzed



Label:

- 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 relation to these technical competences analyzed, was tried to see, as compactly as possible, the integration of Engineering, Business and Design. The answers allows to see that all of them are fulfilled. One can see that some were highlighted, especially those related to the formulation and conception of desirable solutions (I) and design and analyze solutions technically and economically viable (III), that is, once again, the issue of the "creative mind".

The Figure 5 also shows what was expected about the projects having "technical" competences to be developed. An important detail is that even the least explored competences are still a high number in relation to the total: practically 8.3% of the projects have the objective of knowing and ethically applying legislation and normative acts within the scope of professional practice (VII).

In a practical way, for example competence VII, which was the least answered, if from these 15 answers about 20 classes are opened, since the same activity can have more than one timetable depending on student demand, at least 350 students will be reached if these classes are opened, since the activities have about 20 students per class, that is a small demonstration that this "15" is still a very large number and that it can reach a considerable number of students.

Table 1 - PAEs Category

Category Name	Number of answers
Industrial Management	1
Mockups and modeling	1
Citizenship	2
Exact sciences	3
Energy	3
Expression & Imaging	3
Hardware & Embedded Systems	3
Games	3
Robotics & Automation	3
Materials	4
Simulation and computational optimization	4
Cities and urban solutions	5
Data Science	5
Academic competitions	5
Finance	6
Careers	8
Environment and Sustainability	8
Applied sciences	9
Management skills	10
Entrepreneurship	12
Product research and development	12
Engineering solutions	12
Industrial projects and processes	16
Development of socioemotional skills	17
Software training	26

The categories indicate to which area the offered project is directed. The idea is that these projects should be diverse, since we are looking for a nexialist profile and, in this sense, the more areas students are offered, the more versatile they can become. As it is an institution with a strong emphasis on Technology, it is natural to have more courses related to software training.

4 Conclusion

The aim of this work was to create a common list of competences for Engineering, Business and Design programs, so that the competences declared by instructors of projects offered to students from these three courses can be surveyed. The importance of this common list lies in the fact that students from these three courses can enroll and participate in these projects and having a common standard of competences helps in identifying what is being taught in these projects.

The most important initial conclusion is that it was possible to construct this single list, which was validated and allows the identification of common competences among these three courses. A second conclusion is that it was possible to construct a data collection instrument on the projects that allows the instructor to state which competences he intends to develop in the students. The third conclusion was a quantitative survey that allows us to know which competences are being developed in the projects.

All of this allows for a management of the projects offered to students. In this way, it is possible to act so that competencies that appear little in the projects offered to students are encouraged, in order to cover any gaps. This allows a broad vision that helps in the management of the institution's courses.

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An Escape Room For Learning Computer Programming

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Abstract

Game-based learning is a strategy where games are used as a challenge for students to learn and apply the contents of a subject matter. In this sense, game-based learning is an instance of problem-based learning. In this paper we discuss how game based strategies can be used to motivate students to perform the actions required for each of the learning phases. Namely: motivation, information, understanding, application and validation (feed-back). Then we present the application of those strategies to the design of an escape room where computer programs are required to solve the puzzles of the game. The designed escape room is then used as a game-based strategy in an introductory seminar on the Python programming language.

Keywords: Game-based Learning; Escape Room; Learning Phases; Learning Computer Programming.

1 Introduction

An escape room is a game activity where a team of players is confined in an enclosed room and needs to find hints and clues to solve a series of puzzles required to open the locks that open the room. Escape rooms have become very popular in the last decade. In addition to their original purpose as a game, escape rooms have been extensively used in areas such as the enterprise (as team-building routines) and education (as learning environments where puzzles are related to the subject matter) (Call et al, 2021; Lopez-Fernandez et al., 2021).

In the educational field, escape rooms can be used as problem based strategies to guide student teams towards the completion of a set of goals. In a sense, escape rooms can be viewed as a situation from which "students cannot escape without learning" (Cowan 1998; Bofill 2006).

In section 2 of this paper we focus on the different phases of learning (namely: motivation, information, understanding, application and validation or feed-back) (Bofill & Miró, 2007) and, in section 3, we focus on how the use of escape rooms can be used to induce student activities that enhance each of these phases. We then describe our escape room (section 4), and its application to a game-based learning introductory seminar for learning computer programming in Python (section 5). In this escape room, the puzzles require solving computer programming problems, with hints hidden in the course notes and syllabus. Finally, section 6 is devoted to conclusions.

2 The phases of learning

In (Bofill & Miró, 2007) we decompose the process of learning in a sequence of phases, in order to be able to design student activities for each phase. The phases we proposed are the following:

1. **Motivation**, in two senses:
 - a. **Subjective motivation** reflects the attitude of the student towards the subject matter and towards the activity of learning. A student is motivated when she *wants* to learn the contents and, as a consequence, when she is ready to invest some time and effort to this purpose. Subjective motivation can be *intrinsic*, when the student wants to learn because she *likes* it (the reward for the effort is successful learning), or *extrinsic*, when studying is felt as an obligation, and the effort is based on an external reward (or to avoid a punishment). Without some intrinsic motivation, though, learning is bound to fail.

- b. **Motivation of the subject contents.** The subject is well motivated if the student understands the *finality* of what she is about to learn, and its relationship with what she already knows. Subject contents must be contextualised and related to the previous experience of the learner. Motivation of the contents must be accompanied with a clear formulation of the learning objectives (what will the student get to know and be able to do after the learning process).
2. **Information** or acquisition of factual knowledge. The student must be somehow exposed to some sort of explanation of the contents of what she is going to learn. In that phase, the student must gather the information and process it. Information can be transmitted by *frontal teaching*, or with different kinds of *learning materials* such as course notes, problem collections, books, tutorials, presentations, videos and so on.
 3. **Understanding** of the matter. After this phase, the student must be able to explain the subject matter, and to find the relationships between the concepts introduced, and the relationship between new concepts and what she already knows. Understanding requires *significant* learning. Sometimes understanding is confused with learning as a whole: I understand it, therefore I know it. But often this is not the case. The following phases are also necessary,
 4. **Application** is the ability to transfer knowledge onto a different context, and it corresponds to *deep learning*. Knowledge transference involves activities such as the evaluation of the new situation, the identification of the required knowledge for the new context, and the translation of this knowledge to the new requirements. For deep learning to take place, application should go beyond the solution of prototype problems (procedural knowledge) based on a theory (conceptual knowledge).
 5. **Validation** is the required feed-back to assess that we are following the right learning path. Validation is required in all the previous phases: validation of the learning objectives, validation of the factual knowledge, validation of understanding and validation of knowledge transference. Validation requires assessment and feed-back in order to enhance what we did well, and in order to be able to learn from mistakes. In an academic context, validation requires *formative assessment*, as opposed to selective assessment and grading.

Quoting John Cowan (Cowan 1998):

"I take teaching to be: The purposeful creation of situations from which motivated learners should not be able to escape without learning or developing".

The purpose of the above scheme is to help in the design of such situations and activities, for each of the learning phases.

3 Learning Python with a game-based learning approach

The course we want to design is a 20h introductory course to the Python programming language, for students with some programming experience with other languages (C and Java). A "frontal" approach, like explaining the structures and syntax of the language, one after another, would be boring, both for the students and the teacher. Furthermore, computer programming is a *skill* and, like bike riding, it should be learned by practice.

Problem based learning is a resourceful alternative approach, well suited for the situation. In problem based learning, the learner is confronted with a problem that needs to be solved, which requires the study of the subject matter. In this way, the problem is the conductive thread that motivates the need for the subject matter (learning phase 1.b).

Game-based learning can be organised in such a way that one or several problems are embedded in the game. In our case, the student is confronted with an escape room situation where she needs to find clues and solve programming problems to find the passwords that open the locks and produce the passwords of the game. In this way, the student gets involved with the challenges and puzzles of the game, which enhances subjective motivation (learning phase 1.a).

To avoid trivialization, care must be taken not to place too much emphasis on the game: the student must be aware at all times that this is a "serious" game, and that the actual purpose of the game is learning. To this

effect, the programming problems embedded in the game should be sufficiently challenging and attractive by themselves. In our course, the problems include a Morse decoder, a drawing with turtle graphics, an hexadecimal to decimal converter and a fractional number calculator.

Information on the Python language (learning phase 2) is provided with a syllabus and a series of course notes and examples that accompany each of the programming challenges. Besides, in order to motivate students to study these notes, game-related hints are hidden within the notes. Therefore, students need to read the notes in order to be able to proceed with the game.

Understanding of the language syntax and structures (learning phase 3) should be straightforward for students who already know other languages, so the challenge lies in the application of these language structures to the problems that need to be solved (learning phase 4).

Computer programming is a subject that is easy to validate (learning phase 5). A computer program either solves the proposed problem or it does not. In this sense, feed-back is self provided and immediate (if the problem is not too large), and different alternatives can be tested on the spot. Furthermore, the game takes place in the classroom and the role of the teacher is to provide help in developing the computer problems (and, eventually, to provide hints for the game when students get stuck).

Finally, playing games in teams is both more fun and more productive. In our course students are organised in teams of two or three people, and care is taken that each student is involved with the computer programs.

The escape room is designed for 10h of work, altogether. In the remaining 10h the students must invent, design and implement a small programming project with the help of the teacher (Lima et al, 2017).

4 The bridge over the river Splash, an escape-room



Paris 1901, The game starts at the telegraph office of the railway station. Suddenly an alarm goes off and the telegraph machine spits this text:

```
... --- ...  
-... .. -.. --- . -... .- --- -.. -..  
... - --- .-. - .-. .. -  
... --- ...
```

The players must understand that this is a Morse encoded message, and they must build a computer program to decode it. Course notes are provided with all the Python structures required to write the program, and mixed within the notes, there is a table with the Morse code.

Once they finish the program, the decoded text should be the following:

```
SOS
BRIDGE BROKEN
STOP TRAIN
SOS
```

The password to the next screen is the christian name of the inventor of the code.

The players then rush towards the train, which is already leaving the station, but the train platform is too high to jump on it. They manage to figure out that they need a ladder, and they have to write a computer program that uses turtle graphics to draw the picture of a ladder (which they show to the game assistants). The following is one such drawing of a ladder:



Now, they use the ladder to climb onto the train platform but the door is locked. There is a sign that reads:

0x2F3A

The players have to realize that this is a number in hexadecimal format, and they must translate it into decimal notation. To do so, of course, they have to build a computer program that translates any hexadecimal number into a decimal base (the course notes include enough hints to solve the problem). Once they find the answer they introduce it into the lock and they are able to enter the train.

But, alas! Once on the train, the brake gear is quite complicated. There is an instruction panel that says:

Good job! But there is one last problem to solve. The brake works with a gear shift that requires a precise combination of wheels. The right combination is the simplified fraction resulting from the following expression:

$$(8/21 + 3/14) * 3/5$$



Therefore, again, they need to build a computer program that can operate with fractional numbers. Once they find the solution, they enter it and the train stops.



Figure 1. The escape room has been solved with success!!!

In the last window of the game (figure 1), a teacher-based solution of the programs is provided, so that they can compare them with their own.

5 The Python seminar. Running and assessment of the escape room

The Python seminar will take place by the end of June (just before the PAEE/ALE conference) at the Telecoms-UPC school of Telecommunication Engineering. Twenty students will attend it. Without much explanation, the

students will be confronted with the escape-room and they will use the course material to develop their programs, with the help of the teacher.

At the end of the seminar they will be asked to answer the following assessment quiz, which is based on the SEEQ questionnaire (https://teaching.usask.ca/documents/seeq/Standardized_SEEQ_Instrument_at_UofS.pdf).

Statement	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
The game has been a motivation to start working on the subject	1	2	3	4	5
The game has engaged me to practice more	1	2	3	4	5
I have enjoyed learning through play	1	2	3	4	5
The game has helped me to acquire a deeper level of understanding	1	2	3	4	5
I like the fact that I could solve the problems at my own pace	1	2	3	4	5
Mention three positive aspects that you have enjoyed					
Mention three shortcomings or things that you would change or improve					

Table 1. Summary of the proposed questionnaire for the assessment of the activity.

The processed results will be presented at the conference.

6 Conclusion

This paper presented the realisation of an escape room as a means of designing student activities to enhance student involvement in each of the learning phases (motivation, information, understanding, application and validation). The course will take place just before the conference and results will be presented there.

In the meantime, a short version of the escape room has been tested on a different course with good results: students reported interest in moving along the windows of the game, and they were excited to escape the room. They reported that the game provided extra motivation for solving the programming problems involved.

7 Final remark

I asked my friend, Miguel Valero, who has become a reference in cooperative learning and project based learning (Valero, 2022), how he organises his learning activities so that the students get the most out of them. He answered that, most of the time, he was happy enough if the students were active in and out of the class. Learning, he said, is more likely to happen when students are active, rather than sitting and listening passively to the teacher's explanations.

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An Escape Room for an alternative evaluation system

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Abstract

Our traditional education system spins around evaluation and its traditional grading system: summative assessment. In that system, professors spend time and effort trying to be "fair" when they mark the exercises, while students' main concern is snatching enough points to pass. We believe learning should be at the center. Students should put their energy on learning and professors on facilitating this learning process. However, we are still required to give a mark. We propose a game to achieve formative assessment. Play is a source of motivation to both engage students and enhance learning. The aim is that students should learn and enjoy their learning. We have designed an escape room with different sets of questions, each set corresponds to one topic. The student is presented with one activity to solve correctly. There is no grading but feedback: the answer can either be correct or incorrect. If the answer is correct, the student moves on to the next set of questions, otherwise the student is challenged with another activity of the same set. This goes on until the student solves one exercise correctly of each set. The student can only escape the room if one exercise of each topic is solved correctly. All activities proposed are of a basic level and if the student escapes the room he has a pass. Another bundle of sets can be done with more advanced exercises and if the student escapes the room he would achieve a higher mark. The method emphasizes two fundamental (but neglected) aspects of education: (i) the joy of learning; and (ii) diversity, as we give students as many opportunities as they need to learn at their own pace without penalty.

Keywords: Active Learning; Engineering Education; Formative Assessment; Game based learning

1 Introduction

Our traditional grading system is based on the much-dreaded exams. The exam period is a time of the year when students are assessed on the knowledge they achieve during the term and it is a time usually marked by stress, late nights, sore eyes and lots of coffee. With the good intention to alleviate the stress sometimes there is a mid term exam, or even the so called continuous evaluation with its own shortcomings (Armengol, 2007).

In any case, the grading system is based on exams and summative assessment. Students are presented with exercises to solve in a limited time and professors check how well they have done and based on that they give a mark, if the mark is sufficiently high, the student passes the subject.

In this scenario, assessment does not support learning (Gibbs 2005):

- no feedback is given to the students to improve and facilitate their learning,
- Students may not have another chance to test their knowledge or in the best case scenario even if there is another chance they have already been punished with a bad mark, which means that essentially students are not allowed to make mistakes during their learning process. We believe it is by making mistakes and reflecting on them that we learn the most (Farreras 2021).

However, we are still required to give a mark, is there a better way to grade? Yes, Virginia (Linda B. Nilson, 2016).

We propose to challenge the students with a certain amount of exercises that they need to solve correctly to pass the subject - instead of grading the exercise(s) of a test with a mark. There are different sets of questions/activities/exercises (i.e., one set for every subject topic). The student is presented with one activity to solve correctly. There is no grading but feedback: the answer can either be correct or incorrect. If the answer is correct, the student moves on to the next topic, otherwise the student is challenged with another activity of the same set. This goes on until the student solves one exercise correctly off each set (or topic).

We present this evaluation method as a Game-based learning (GBL) activity: an escape room. The student can only escape the room if one exercise of each topic is solved correctly. By introducing Game-based evaluation (GBE) into our subject we aim to achieve the following:

- Rescue the **joy of learning**. Learning for the sake of learning is actually a very enjoyable and fulfilling activity. Joy and fulfillment are undermined by the pressure the traditional evaluation system puts on the students (Bofill, P. 2005). Learning should not be seen as a sacrifice but as a privilege.
- **Enhance learning**. Students will gain deeper knowledge as they engage in the activities with the purpose of solving them correctly, meeting the specifications of each problem. They will work on each problem until they complete it. As opposed to doing what they can and hopping the mark is over the pass line.
- **Engage students**. By engaging them on the challenges of the game, students will practice more and practice makes better.
- **Allow mistakes**. Enough exercises are provided so that they can have as many attempts as they need, allowing them to make mistakes without affecting their mark. Students can learn at their own pace, accommodating a diversity of learners.

Overall, this paper makes the following contributions:

- We present our **design and implementation of a escape room** for First Year students of Computer Structure I course in the Degree in Informatics Engineering curriculum. There are 50 students per course divided into 3 groups for the practice sessions.
- We present a novel form of **evaluation in the form of a game GBE** that is stress free, for students and professors, accommodates diversity of learners, engages students and enhances learning.
- We present our expectations and our plans and methodology to **evaluate the activity** (the escape room). The activity is taking place at the time this paper is being written so we have not had the chance to evaluate the outcomes yet. If the paper is accepted we plan to present the results at the conference.

The rest of the paper is organized as follows: Section 2 presents the design of the escape room game; section 3 discusses the evaluation aspect of the game; section 4 shows its implementation; section 5 evaluates the outcome of the activity; and concluding remarks are written in section 5.

2 Theoretical framework

Recent research has applied gamification to many educational contexts, including Computer Science courses (Call, 2021)(Lopez-Fernandez 2021). However not all gamification strategies are equally fruitful. As in (Dave Eng, 2019), we make the distinction between gamification and Game-based learning (GBL). As opposed to gamification GBL does not encourage competition, which is not an intrinsic source of motivation. In GBL the students get involved in studying and solving subject matter problems to get the required hints to continue the game. In this sense, game-based learning is an instance of problem-based learning as it complies with the characteristics of PBL (Graaff, E. 2003).

PBL has long been proven to be an effective way to engage students and enhance learning (Yunita 2021) (Chevalier 2021) (Lima 2017).

According to (Bofill, 2007) learning takes place in five stages. Namely: motivation, information retrieval, understanding, application (or practice) and feed-back. We have chosen an escape room over other gamification activities because in an escape room (and in general in GBL) a challenge is set for the students (in the form of a game) and they have to learn the contents of the subject and apply them in order to solve the riddles to progress through the game and escape the room. In this way, GBL reinforces the autonomous realization of each of the learning stages.

Concerning assessment, we aim to achieve the conditions defined by (Gibbs G., Simpson C. (2005)) under which assessment supports learning. They can be summarized as: Providing the right activities and timely formative assessment which is used by the students and does not affect the grading. The escape room is a good framework as feedback is provided immediately at every attempt and there is always another chance. It also enables us to grade according to the system explained above.

3 Designing the game

The definition of an escape room: a game in which participants confined to a room or other enclosed setting (such as a prison cell) are given a set amount of time to find a way to escape (as by discovering hidden clues and solving a series of riddles or puzzles).

We have designed an escape room that seeks to have an epic mission, a clear goal, immediate feedback, another chance to prove it and a positive social dimension (McGonigal 2011). Careful consideration has also been given to each exercise so that students cannot escape without learning (Bofill, 2007).

3.1 The context

The escape room presented here was designed as a part of a Teaching Innovation Project to introduce Game Based Learning (GBL) into first year subjects with the aim of fostering (cooperative) learning, engaging students, and providing a positive social dimension. It is an interdisciplinary project that involves 3 different schools of Engineering education in our University where GBL has been introduced in 4 different subjects. The project involves 3 different schools of Engineering education in our University and GBL has been introduced in 4 different subjects. This paper focuses on the experience in the Computer Structure I course (ESC1), which belongs to the first year studies of the Bachelor's degree in Informatics Engineering curriculum offered by the Polytechnic School of Engineering of Vilanova i la Geltru (EPSEVG).

3.2 The set up or mise en place

The story line is as follows: there is a train at the platform about to take off when suddenly an urgent message arrives at the station office about a fallen down bridge on the route of that train. The train needs to be stopped! (epic mission). However it has already left the station and its communication system is broken. So you need to jump onto the last coach and make progress from coach to coach until you reach the locomotive engine at the driver's compartment where the driver is going to test you before taking your advice to stop the train (the goal).

Each coach has a security system: (i) first there is a password at the door that you need to guess; and (ii) an alarm that you need to deactivate in a given amount of time, before a bomb explodes and the train blows up. Each team needs to move ahead from coach to coach, and each coach is locked with a unique password that all teams need to figure out together.

Once they get to the engine, the teams meet the driver and there is one final challenge as the driver is a cautious person and gets suspicious when you break into the train engine's room and ask him to stop the train. So he locks each person alone into the room, from where you can only escape by answering correctly to 5 questions. Only then will the driver be convinced that you are a trustable person.

3.3 The challenges and the course timeline

The escape room is made of three types of challenges. It is a cooperative game, so the students work in teams of 2 or 3 students, chosen by themselves. Teams do not compete but work together towards achieving the goal. The games start in the classroom at the practice sessions, where the whole class is split into three smaller groups, and can be finalized at home.

The first session will be spent presenting the game, signing a contract to set up the rules and responsibilities and setting up the working environment for the practice sessions with the computer (lab sessions).

3.3.1 Challenge 0: Consult the reference book

The first (preliminary) challenge is to jump into the train before it leaves the station and unlock the door of the last coach. The riddle is a question which answer can be found in the reference book of the subject so teams need to visit the school library. Once they have the password they can begin.

Each coach represents a practice session at the lab. These sessions run every fortnight and there are 4 lab sessions during the course. Each lab session has two parts, that we have linked to our next two challenges:

3.3.2 Challenge 1: Deactivate the alarm

(i) First, there is a pre-assignment the students need to complete beforehand. Once in the classroom, answering correctly to a set of questions related to the pre-assignment will deactivate the alarm. These questions are the same for all groups and a limited amount of time has been given for them to answer the questions before the timer expires.

3.3.3 Challenge 2: Unlock the door to the next coach

(ii) During the rest of the lab session the students work on some codes to practice the topics that have been introduced into the theoretical lessons. They are presented with a problem to solve that is split into tasks of equivalent difficulty and educational content and each team takes one task (there is a riddle to solve to figure out which task each team needs to solve). The tasks need to be combined to solve the problem and only the correct answer to the problem will give the right password to unlock the door to the next coach. The teams need to work together making the game cooperative and providing a positive social experience.

After answering each question immediate feedback is provided and they have as many attempts as they need in the given time. Students work in teams in challenge 1 but in challenge 2 teams need to work together making the game cooperative and providing a positive social experience. All activities proposed for challenge 1 and 2 are of basic level and if the group reach the driver's compartment, they have a pass.

3.3.4 Challenge 3: The driver's test

This is a final individual challenge, students reach this point towards the end of the term. In this challenge another bundle of questions is used of a higher difficulty. There are 5 sets of questions which correspond to the 5 topics of the subject matter. In order to escape the room each student needs to respond correctly to one question of each set.

The student is presented with one exercise to solve correctly. If he succeeds in providing the correct answer (feedback is immediate), he moves on to the next set of questions, otherwise the student is challenged with another activity of the same set (mistakes are allowed!). The new activity will be a different one but equivalent in the sense that it relates to the same topic. All activities in one set cover the same educational content. This goes on until the student solves one exercise correctly off each set. In that way he has covered the full content of the course.

The students who pass the driver's test and escape the room will obtain a higher mark.

All challenges preserve our ethos, each team works at their own pace, formative assessment is given and the teams work in a cooperative way.

4 Game Based Evaluation

Using an escape room game for grading the students' progress is a novel form of evaluation as it shifts the focus from (a) a scenario where students try to solve a task(s) the best they can and are given points according to how well they did; to (b) a scenario where there is a set of tasks and students are asked to solve one of them correctly. In (b) they can have as many attempts as they need (limited only by the number of tasks on the set), for each attempt there is formative assessment so the student can progress.

The task can be a single one which covers the full content of the subject matter or several smaller tasks, one for each topic of the subject. And the level of the tasks may vary, there can be bundles of exercises at different levels (basic, medium, high) and the mark could be set depending on how many bundles the student can solve correctly. Students who complete the basic set correctly, but fail to complete the medium set, may have a pass, but students who complete the basic set plus the medium they may have a higher mark, and the highest mark can be achieved by completing the 3 sets.

As (Linda B. Nilson, 2016) states it: all assignments and tests are graded satisfactory/unsatisfactory (pass/fail), depending on whether the work meets its specifications. In this way the students need to correctly solve a certain amount of exercises in order to pass the subject instead of grading the exercise(s).

In this way, formative assessment is provided at every attempt and assessment is used to support the learning (Gibbs G., Simpson C. (2005)).

In our subject we have used the escape room to grade the practical work, which is part of the final mark of each student. It is a cooperative game, so even if there are teams, the full class (lab groups) either succeeds or fails. If they succeed to stop the train on time they will be graded the practical work with a pass (minimum). The students who also pass the driver's test will have a higher mark (7/10). Students have also delivered tasks which will be used to grade the teams beyond 7.

This is the first time we implement GBL in the subject, our set of questions covers the basic and intermediate levels, the former used for challenges 1 and 2, and the later for challenge 3. The game-based Evaluation methodology presented has only been used to grade the practical sessions for now.

5 The escape room implementation

For the implementation we looked at several available tools: Socrative, padlet, moodle questionnaires among others.

The logistic requirements of the game are: (i) possibility to play online (if necessary); (ii) engaging for students, it involves an stimulating and appealing graphical interface; (iii) and it should be possible (and fairly straightforward) to implement our challenges (escape room style).

We finally settled on a combination between genially (<https://genial.ly/>) and moodle questionnaires (<https://docs.moodle.org/>). Challenge 1 was fully implemented on genially with a nice graphical interface. Challenges 0 and 2 were synchronizing moodle and genially. And Challenge 3 was fully implemented using moodle questionnaires.

Figure 1 shows two of the introductory screens of the game; (a) presents the mission and (b) is the interactive map of the train that they can use to navigate for every lab session. All lab sessions are locked until the password is obtained, in due course.



Figure 1. Image of the first screens of the game (a) the mission; (b) the interactive map

We found that Genially gave us a nice graphical interface but the type of questions was limited. *Multiple choice* question type is available by default (shown in Figure 2 (a)); and we have installed a plugin to support the *Short answer* type of questions (shown in Figure 2 (b)). On the contrary moodle has a richer repertory of question forms which allowed us more elaborate questions (https://docs.moodle.org/400/en/Question_types).

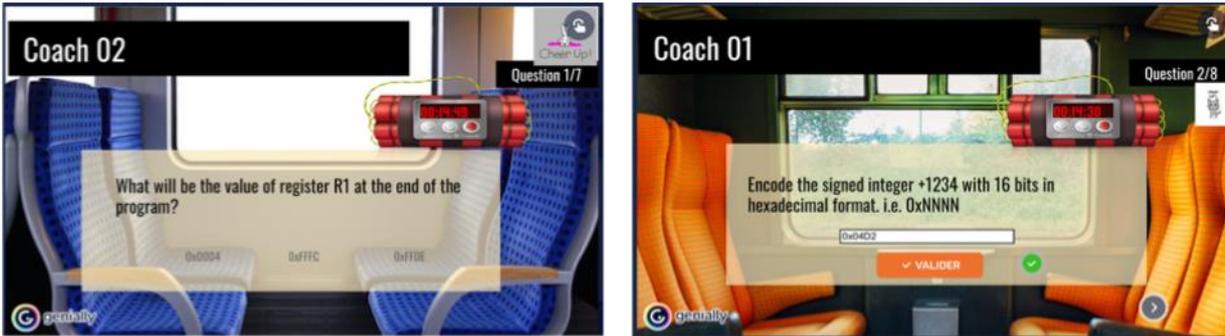


Figure 2. Image of the two types of question we used in genially (a) single choice; (b) short answer

Figure 3(a) shows the password page that locks each lab session (the key to open the coach door), which at the same time, allowed us to synchronize with the timeline of the course using a single genially. Figure 3(b) shows the final page after challenge 1 is completed on couch 2. In this page we give a small riddle which allows us to synchronize with the moodle platform.



Figure 3. Image of (a) password that locks the door of coach 2 on the left; (b) Final pages after succeeding to disconnect the alarm.

Figure 4 shows what happens if things go wrong. Figure 4(a) shows a train accident, the train falling down on the broken bridge, and 4(b) shows a bomb explosion when failing to disconnect the alarm. The good news is that this is a game and the student can always go back and have another chance.



Figure 4. Image of (a) a falling down train, when a question is answered incorrectly; and (b) the bomb explosion if the timer expires.

6 Outcomes and evaluation

At the time the paper is being written we are halfway through the term and the students are carrying on the activity. At this point all we can say is that they seem to be enjoying themselves with the game and fully

engaged with it, we have full attendance to the classroom and we have not had any student withdrawing the course up to this point.

In order to evaluate the activity and improve it for later editions we have prepared a questionnaire based on the Student Evaluation of Educational Quality (SEEQ) Standardized Instrument. Table 1 below shows the questions related to the game and the evaluation methodology. We will ask the students to fill the questionnaire and if the present paper is accepted we pretend to present the results at the conference.

Statement	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
The game has been a motivation to start working on the subject	1	2	3	4	5
The game has engaged me to have more practice	1	2	3	4	5
I have enjoyed learning through play	1	2	3	4	5
The game has helped me to acquire a deeper level of understanding	1	2	3	4	5
I like the fact that I can have as many attempts at the exercises as I need	1	2	3	4	5
I think the evaluation methodology of the lab is adequate and fair	1	2	3	4	5
Mention three positive aspects that you have enjoyed of benefit from regarding the game (lab sessions)					
Mention three shortcomings of things that you would improve on the game (lab sessions)					

Table 1. Summary of the questionnaire based on SEEQ regarding GBL and evaluation methodology

7 Conclusion

This paper presents a Game Based Learning (GBL) activity where we use an escape room not only to engage students and enhance learning but also as a form of evaluation (Game Based Evaluation). We present the students with a set of challenges that they need to solve correctly in order to escape the room, save the train and pass the subject. If they fail to complete one exercise another opportunity is given, with another exercise covering the same educational content. In this way the students need to correctly solve a certain amount of exercises in order to pass the subject instead of grading how well they have completed the exercise(s).

GBE provides a stress free evaluation methodology that emphasizes two fundamental (but neglected) aspects of education: (i) the joy of learning; and (ii) diversity, as we give students as many opportunities as they need to learn at their own pace without penalty.

8 Acknowledgement

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Lecturer Self-Awareness Index: measuring the alignment between lecturer and student perception

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Abstract

During last decades, there was a transformation in the Engineering Education field that resulted in the widespread use of Active Learning techniques, with the goal to place the student at the center of the learning process. However, there was a lack of effective ways to evaluate how a course uses those techniques. Although Active Learning has already been validated as an effective way to influence student learning and is increasingly being validated into the classroom, there was no way to qualify and evaluate the use of Active Learning techniques by faculty members, until the proposal of a conceptual model, called Engineering Education Active Learning Maturity Model (E²ALM²). The application of E²ALM² uses questionnaires applied to course lecturers and their students. This article proposes the Lecturer Self-Awareness Index (LSAI), that derives from E²ALM², as a complement to measure the discrepancy between lecturer and student perception. LSAI allows a lecturer to identify items in which his perception diverges from students'. This tool can help improve decisions in course preparation and lead to a better delivery.

Keywords: Active Learning; Engineering Education; assessment; self-awareness

1 Introduction

One of the great challenges of higher education in the 21st century is to adapt traditional teaching techniques to the reality of today's students, who have different characteristics from previous generations (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).

Engineering Schools eager to modernize educational practices need to understand their current maturity of Active Learning, which can be the first step of a renovation program. To achieve this goal, Arruda & Silva (2021) present the Engineering Education Active Learning Maturity Model (E²ALM²). This framework processes data collected from students and lecturers of a course to depict the current maturity level of the Active Learning implementation in terms of five dimensions, composed of 14 key success factors (KSF) that summarize 41 constructs.

Self-awareness is positively associated with transformational leadership (Titrek & Çelik, 2011), leadership performance and success (Axelrod, 2012; Caldwell & Hayes, 2016; Showry & Manasa, 2014; Whetten & Cameron, 2016). It leads to better decision making, once it connects the past and present experience (Kamenov, 2013), and supports effective learning, because the more students know their 'self', the better they increase their own personal developments (Murphy, 2007). Furthermore, self-awareness increases sympathy (Boyer, 2010; Gair, 2011; Smith, 2011), reduces egocentrism (Gendolla & Wicklund, 2009; Scaffidi Abbate, Boca, & Gendolla, 2016), and is perceived as central to improving management skills (Whetten & Cameron, 2016).

Regardless of the specific maturity level in active learning implementation, the perceptions of students and lecturers can be quite misaligned, due to the natural difference in points of view. The aim of the Lecturer Self-Awareness Index (LSAI) is to depict these possible discrepancies and provide the decision-making process with feedback between how lecturers and students perceive the benefits and characteristics of a given active learning implementation.

In this article, the concept of self-awareness is emphasized, bringing some definitions, motivations, and limitations. Additionally, the concept of Active Learning is presented, followed by E²ALM² details. Then, LSAI is

defined and detailed. Finally, we conclude with some discussions about the advantages and limitations of the index.

2 Self-awareness

Although the term self-awareness is widely used in practitioner and scientific publications, the exact meaning of the term is still unclear (Carden, Jones, & Passmore, 2022). The literature brings several definitions of self-awareness (Nutt Williams, 2008; Sutton, 2016; Sutton, Williams, & Allinson, 2015), but confusion between the concepts of self-awareness, self-knowledge and self-consciousness is common (Morin, 2017; Sutton, 2016). Also, definitions seem to depend on focus and context (Sutton, 2016).

Goleman (1995) defines self-awareness as “knowing one’s internal states, preferences, resources, and intuitions”. There are statements that self-awareness refers to the constant consciousness of feelings, thoughts and behaviors (Harrington & Loffredo, 2010; Nutt Williams & Fauth, 2005) and how someone’s behaviors impact other individuals (Mayer, Salovey, & Caruso, 2004).

In their systematic literature review, Carden et al (2022) offer the following definition:

“Self-awareness consists of a range of components, which can be developed through focus, evaluation and feedback, and provides an individual with an awareness of their internal state (emotions, cognitions, physiological responses), that drives their behaviors (beliefs, values and motivations) and an awareness of how this impacts and influences others.”

However, self-awareness is a difficult journey. Practicing it may feel risky and frightening for some students, and its development requires a safe learning environment (Feize & Faver, 2019). In the process of developing self-awareness, a person might find discrepancies between the real self and the ideal self (Gallwey, 2001; Silvia & Duval, 2001).

Finally, Govern and Marsch (2001) discuss the manipulation and measurement of levels of situational self-focus. Titrek (2011) analyses the Self-Awareness Competence Scale and Demerouti et al (2011) state that a high level of self-awareness could be considered as a high consistency between self-evaluation and the evaluations of others.

3 Active Learning and its assessment

Despite the vast literature available on Active Learning, there is still no consensus definition on the topic. Hartikainen (2019) shows 66 definitions grouped by three main categories: (1) defined and viewed as an instructional approach; (2) not defined but viewed as an instructional approach; and (3) not defined but viewed as a learning approach. We highlight three popular definitions: “any instructional method [used in the classroom] that engages students in the learning process” (Prince, 2004), “an umbrella term for pedagogies focusing on student activity and student engagement in the learning process” (Roehl, Reddy, & Shannon, 2013) and “an umbrella term that now refers to several models of instruction, including cooperative and collaborative learning, discovery learning, experiential learning, problem-based learning, and inquiry-based learning” (Barkley, 2010).

In the Engineering Education field, it is possible to identify several movements with the objective of modernizing programs and teaching process, such as the CDIO initiative (Crawley, Malmqvist, Östlund, Brodeur, & Edström, 2014), the change in ABET's accreditation criteria (called EC2000) (Lattuca, Terenzini, & Volkwein, 2006), and the greenfield creation of engineering colleges with proposals totally different from the traditional 20th Century model, such as Olin College (Goldberg & Somerville, 2014) and Aalborg University (Mohd-yusof, Arsat, Borhan, Graaff, & Kolmos, 2013).

A common point among the modernization movements in the engineering education field is the recommendation to place the student at the center of the learning process, which drives the increasing use of active learning techniques (Hartikainen et al., 2019).

From the consensus on the importance of using Active Learning techniques, there are different levels of maturity in this subject. At one extreme, it is possible to observe isolated actions of teachers who experience a change in a course. At the other extreme, there are programs designed as project-based, with materials and assessment methods aligned, in addition to adequate infrastructure for classes in formats different from the traditional model, in which students attend the class in rows watching a lecturer in front of the classroom.

Considering the growing popularity of these techniques, Arruda & Silva (2021) introduce the Engineering Education Active Learning Maturity Model (E²ALM²), a framework that allows practitioners to assess the current maturity level of Active Learning implementation in a course. This framework can support diagnosis and practical improvements in real settings.

3.1 E²ALM² method

The Engineering Education Active Learning Maturity Model (E²ALM²) (Arruda & Silva (2021) was built from a literature review of key success factors (KSF) for Active Learning implementations, which were divided into five dimensions: content quality, organizational environment, organizational infrastructure, lecturer and interactions. These five dimensions are subdivided in fourteen KSF. Each KSF is composed of one or more constructs, adding up to 41 constructs in total. Each construct is detailed in variables, totaling 89 of them.

At the lowest level, each variable has a grade. To apply the model to real cases, two questionnaires are used: Student Questionnaire (SQ) and Lecturer Questionnaire (LQ). Figure 1 shows the E²ALM² structure and those questionnaires.

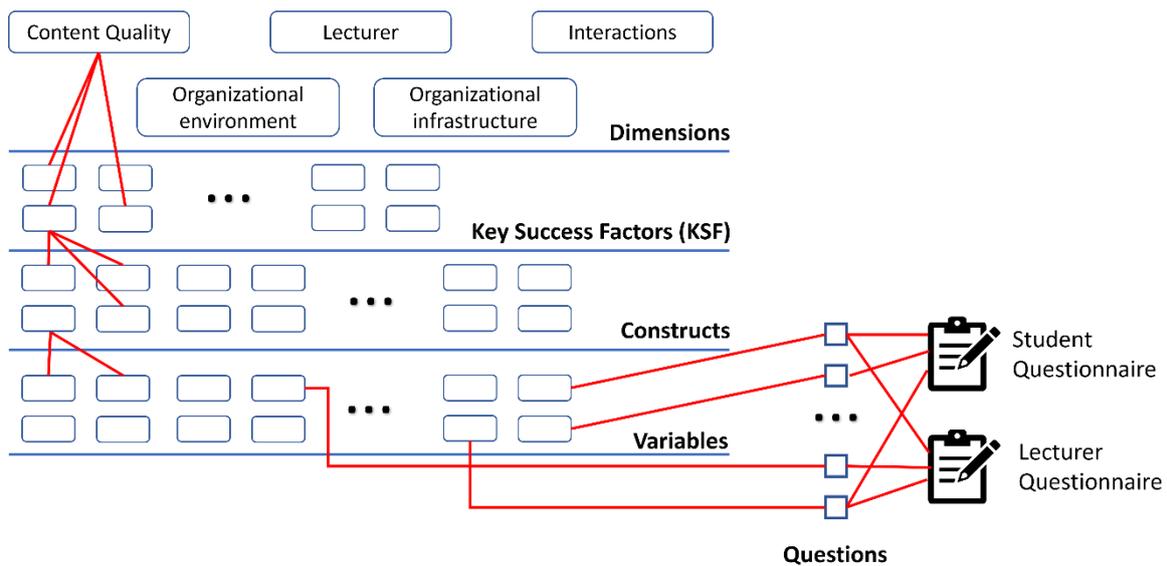


Figure 1 - E2ALM2 structure and questionnaires

Each question in the questionnaires is linked to a variable, and based on the result obtained in this question, a value is assigned (Question value). Figure 2 shows the condition to calculate this value. From the Question Value of all questions, the score for the linked variable is calculated. The construct score is the average of the variables that compose it. The KSF score is the average of the constructs that compose it. Due to its nature, there are variables that are present in both questionnaires and others that are present in only one of them.

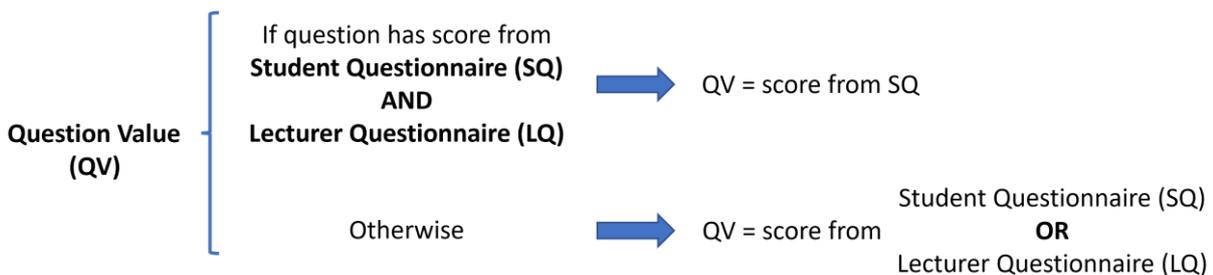


Figure 2 - Question value condition

Then, to calculate the dimension score, the grades of the KSF that compose it and the weights are used, calculated from the application of the Analytical Hierarchy Process – AHP method (Saaty, 2008), with answers from paired comparisons of importance between the KSFs that make up the evaluated dimension. These answers were provided by Active Learning experts consulted specifically for this purpose. Figure 3 shows the process to calculate the dimension score.

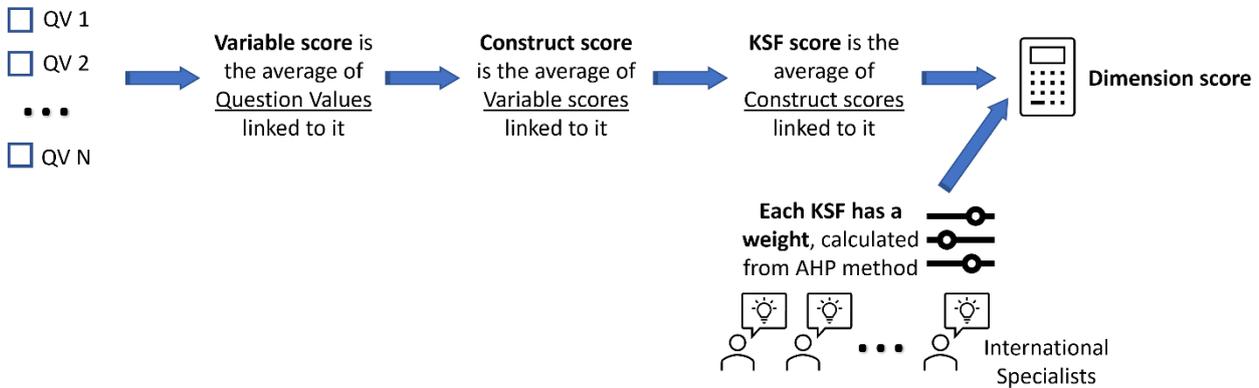


Figure 3 - Dimension score process

4 LSAI Method

As the application of the E²ALM² is based on the responses of the students and the lecturer, it is possible that there are divergences between the perceptions of both sides. Due to this fact, the Lecturer Self-Awareness Index (LSAI) was created as a way of identifying the discrepancy between the two points of view. Figure 4 shows the E²ALM² framework and its KSFs that make up the LSAI.

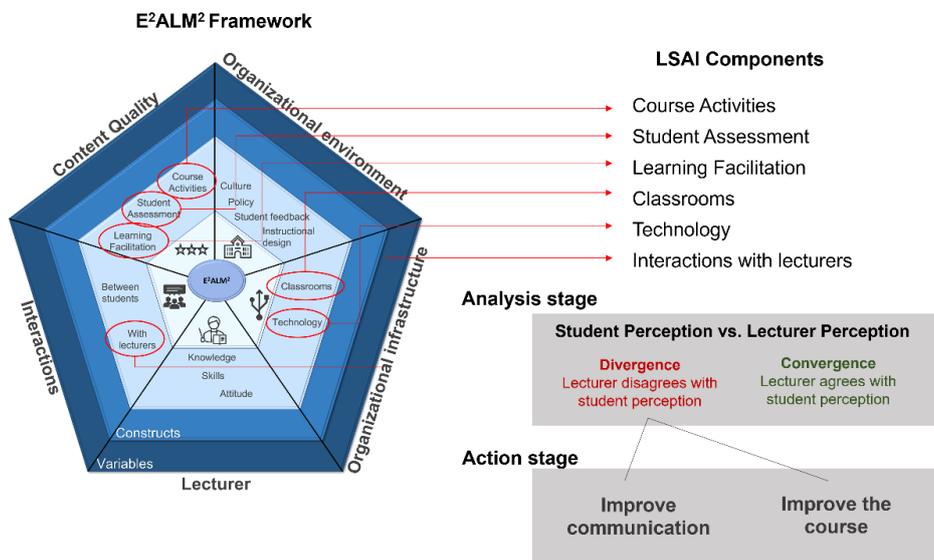


Figure 4 - E²ALM² framework and LSAI components

Due to its nature, LSAI can only be calculated from KSF that have both student and lecturer measurements. It is calculated from the difference of each question in the Student Questionnaire and in the Lecturer Questionnaire. The maximum value (5) indicates that the lecturer's perception is fully aligned with the students' perception, while the minimum value (0) indicates the total misalignment between the two perceptions.

4.1 LSAI composition

The constructs that compose the LSAI calculation (those that have scores in both the SQ and the LQ) are shown in the Table 1.

Table 1 - LSAI constructs and Key Success Factors

Construct	Key Success Factor	Dimension
Use of real-life problems	Course Activities	Content Quality
Application of active experiments	Course Activities	Content Quality
Variety of instructional resources	Course Activities	Content Quality
Adequacy to Learning Outcomes (LO)	Course Activities	Content Quality
Clearness of assessment methods	Student Assessment	Content Quality
Clearness of criteria for success	Student Assessment	Content Quality
Communications with students	Student Assessment	Content Quality
Preparation of students to conduct activities required	Learning Facilitation	Content Quality
Classrooms designed for improve active learning experience	Classrooms	Organizational infrastructure
Classrooms equipped with technologies to enhance student learning and support teaching innovation	Classrooms	Organizational infrastructure
Availability of technology	Technology	Organizational infrastructure
Accessibility of technology	Technology	Organizational infrastructure
Usability of technology	Technology	Organizational infrastructure
Interactions students/lecturers	Interactions with lecturers	Interactions

As shown in the table 1, LSAI is calculated from just six KSF: Course Activities, Student Assessment, Learning Facilitation, Classrooms, Technology e Interactions with lecturers.

According to Arruda & Silva (2021), those KSF have following specifications:

- Course Activities (problems, projects or cases studied) should: engage students with real-life problems and active experiences; provide students with a variety of additional instructional resources, such as simulations, case studies, videos, and demonstrations; be suitable to achieve different targets including the support of the students' learning process and establishing learning outcomes requirements; be clearly written, in the right length, useful, flexible, and provide appropriate degree of breadth; have suitable intellectual challenge; and begin with an explanation of its purpose.
- Student Assessment needs to be clear, concise, and consistent. This involves instructions, assignments, assessments, due dates, course pages, and office hours. Furthermore, criteria for success must be communicated clearly and monitored.
- Learning facilitation includes the preparation of students to conduct activities and tasks required in addition to activities related to the facilitator guiding the learning process of the students. It also involves providing students with regular opportunities for formative feedback from the lecturer.
- Classrooms should be designed for improve Active Learning experience and be equipped with technologies that can enhance student learning and support teaching innovation.
- Technology involves availability, reliability, accessibility, usability of devices, internet (Wi-Fi), learning support, and inclusive learning environment.
- Interaction between students and lecturer supports knowledge construction, motivation, and the establishment of a social relationship. Furthermore, constructive, and enriching feedbacks from the lecturer lead to increasing academic success and feelings of support.

As can be seen in the specifications above, in addition to the nature of the LSAI, all the KSFs that make up this indicator have the potential for different perceptions by the lecturer and the students. However, the capacity to trigger actions to improve the course (and the conditions that surround it) is much more concentrated on

the lecturer than on the students, because although the lecturer acts as a facilitator and co-constructor of learning, he has a role in the organization structure. This way, it is possible to identify students as clients of the service provided by the organization and it is essential that there is a way to assess how much the lecturer's perception is in fact aligned with the perception of clients (students) in relation to this service.

5 Discussion

The application of E²ALM² allows the diagnosis of a course in the five dimensions that make up the index, as already discussed. As a way of representing the result, a radar chart is constructed, as in figure 5.



Figure 5 - Example of E²ALM² real application

For each KSF, lecturer and student perceptions may converge or diverge. Possible combinations are shown in figure 6.

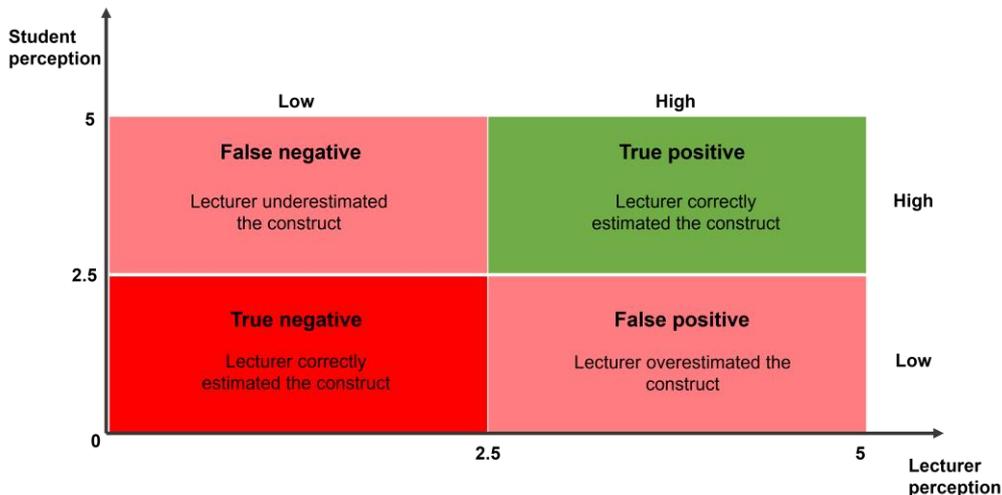


Figure 6 - Student and lecturer perceptions

From the answers to the questionnaires, the LSAI in your six KSF is also calculated. The line LSAI = 0 is the bisector of the quadrant shown in the figure 7. Analyzing the example shown as follows, it is possible to identify that the KSF in which perceptions are most discrepant is "Classrooms".

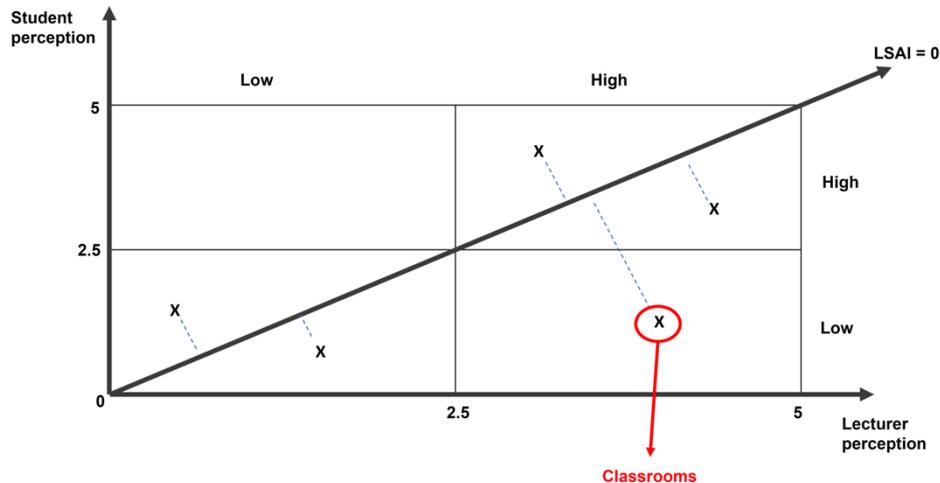


Figure 7 - LSAI results

In this example, KSF “Classrooms” is a component of the dimension “Organizational infrastructure”, which had the lowest grade between five dimensions of E²ALM². Then, while this dimension is possibly a course weakness, the lecturer’s and students’ perception are misaligned. This way, any effective improvement action could be hampered.

Looking at this example, two variables of KSF “Classrooms” are shown: (i) % of activities performed in an environment suitable for Active Learning and (ii) % of activities performed in a technologically appropriate environment. So, if the lecturer is not concerned with finding more suitable physical spaces for the activities of the course, this indicator will hardly improve. Thus, students’ perception of quality will remain compromised. Here, it is important to remember that self-awareness as considered as central to improving management skills (Whetten & Cameron, 2016).

As a limitation, it is important to highlight that E²ALM² does not assess the quality of a course but identifies the maturity level related to active learning. In addition, data collection made only with questionnaires can lead to bias or have answers that reflect some student dissatisfaction with other factors. Finally, it is essential to highlight the importance of validation of the questionnaires, to eliminate another kind of bias. This validation is still planned to future steps.

6 Conclusion

Active Learning is a broad concept that has been boosted during last years, especially in the Engineering Education field. As a first step to an improvement plan, it is necessary to diagnose the status of a course. Then, to assess the maturity level of an AL implementation, E²ALM² is used.

Additionally, self-awareness is understood as an important capacity to high levels of leadership, better decision making and management skills. Thus, this concept is intrinsically linked to the path to improvement actions, with the goal of upgrading course conditions and evaluation.

After E²ALM² application, some factors can show misalignment between lecturer’s and students’ perceptions. To identify this discrepancy, this paper presented Lecturer Self-Awareness Index (LSAI). This index supports the identification process of critical factors that need special attention to get better results to students.

As future work, we suggest a quantitative study, comparing different applications of E²ALM². This study is ongoing and will be the subject of future work. Initially, it was focused on five courses, from Brazil and Portugal. These cases are being studied and will serve to better understand both the application process and the search for cause-effect relationships between practices and results, in addition to serving as a basis for the validation of questionnaires, the main information collection tool. This could be a start of a predictive model, that can provide hints and suggest approaches to enrich courses.

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Gaming for learning

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Abstract

In the subject of wave optics, we seek to involve students in their learning through active learning techniques. Students participate in large group classes doing small activities, competition games, solving problems,... They are also very active in the laboratory sessions (half the total time of the course) where they measure and analyze the contents developed at the large sessions. The activities they play in the large group are based on gamification principles; students answer group quizzes and get a ranking based on whether or not they get the right answer. We have set out to better develop the possibilities of game-based learning by redesigning the simulation activities that students carry out based on the principles of McGonigal¹ so that they are games from which they cannot escape without learning. The simulation activities have been included in an escape room where students play in groups and to advance in the game they must solve a riddle using the knowledge developed in the subject. As McGonigal proposes, the escape room seeks to have an epic mission, a clear goal, immediate feedback and another chance to prove it, and a positive social dimension.

Keywords: Active Learning; game-based learning, serious games, motivation.

1 Introduction

Gamification has entered strongly into many areas of training, training for industry⁵, training for the financial sector⁶, and of course university education (Call, 2021; Lopez-Fernandez, 2021). Game-based learning has gained significant notoriety in recent years, accompanied by the development of computer tools that facilitate the implementation of quizzes, competitions, simulations, WebQuests, escape rooms, ...

Both the gamification of educational activities (introducing points, badges, and leaderboards) and game-based learning activities (where students learn while playing) increase students' motivation to complete learning activities. However, how does this extra motivation help us as teachers to achieve the learning outcomes scheduled in the course? Are there any gamified activities that are best suited to achieve some results or others depending on the level of the goal set?

An interdisciplinary teaching innovation group at the UPC set out to work on game-based activities to achieve deeper learning by taking advantage of the extra doses of motivation that students show when participating in gamified activities.

2 The subject

Wave optics is a core subject and is taught in the second semester of the degree in optics and optometry at the School of optics and optometry in the Universitat Politècnica de Catalunya. The first two semesters of the degree form the selective phase and therefore, the subject is part of this phase. The selective phase is a set of subjects that are assessed together and must be passed in a maximum period of twice their duration. In case of not passing the selective phase, the student cannot continue the degree.

⁵ <https://trainingindustry.com/articles/learning-technologies/game-based-learning-vs-gamification-do-you-know-the-difference/>

⁶ <https://www.forbes.com/advisor/banking/how-gamification-can-help-you-meet-financial-goals/>

The subject has 6 ECTS, which are transformed into 2 hours a week with the big group and 2 hours of laboratory work for approximately 15 weeks. The second semester of the degree is characterized by its hardness, many subjects with new content and many laboratory practice sessions. This fact, together with the fact that the contents are related to the fundamental aspects of the discipline and that it is difficult for students to see their application, leads us to the initial motivation for the subject being low.

In the normal period (2nd Q) 90 new students are enrolled. They are divided into two big groups (50 + 40) and seven groups of laboratories (x15). Attendance is very dissimilar among big groups and very high among all laboratory groups.

2.1 Contents

The subject has a syllabus that extends over the generation, propagation and detection of light. Themes are covered by considering light as an electromagnetic wave. The properties of the waves and how they are presented in the light are studied.

2.2 Methodology

Students have all the material they need to follow the course on the intranet. This material includes a detailed study guide with the activities to be carried out to learn the contents of the subject. The homework consists that the students have to write summaries of the contents to be treated in the subject from the reading of the chosen material, try to solve small exercises, share the exercises with the classmates and give them feedback, use some simulations to check the phenomena explained in class and solve some problems where the usual topics of the topic appear.

In the course, we propose for the big group sessions to combine expository classes with informal cooperative learning activities. Some of these activities are games (group quizzes where students get small rewards such as winning a race, ...) that seek to keep students up to date.

Completion of activities is also listed on a leaderboard that motivates students to stay up to date.

2.3 The laboratory

In the laboratory sessions, students carry out guided experiments to check the most important laws explained in the large group sessions.

In the laboratory, each group (3 people) has a set-up to do the experiments of the session and must be able to deliver at the end of the session a dossier with the completed report of the work. The dossier should consist of: a summary of the theory related to the experiment they will carry out, the numerical results, graphs, etc., the answers to small questions given in advance by the teacher and as a most important element, the conclusions and final comments of what they worked on in the session.

The groups work cooperatively, they deliver a single consensual dossier for which all members are responsible, exchange roles within the group (prepare reports alternately), conduct examinations individually, and are rewarded if the individual performance of all group members is high... The handout of the experiments tries to foster interaction within the group (discussion of outcome graphs, individual measurements and comparison of results...). Each week, students receive feedback from the teacher on reports from the previous session (Gibbs, 2005).

Laboratory sessions allow us to work on transversal competencies over relatively long periods. So, we spent the first half of the semester working on the written expression. In these laboratory sessions, students should write comments on the results (in the form of a graph) obtained explaining the observed behaviours. In the second half, we work on the accuracy and precision of the measurements. Students develop techniques to try to improve the accuracy of the measurements they make and to know the precision with which they make these measurements.

The experience of the last courses is that the laboratory sessions are very positive and beneficial for the performance of the students. The groups in the laboratory work very well and their overall performance improves a lot.

2.4 Assessment

The assessment of the subject is divided equally between the big group sessions and the laboratory sessions, as the time spent by the students in each one is the same.

The School of Optics and Optometry only reserves a time slot for each subject at the end of the semester to take exams in the big groups. All other tests are carried out during the hours assigned to the subject. In these spaces, we propose to the students four controls with a weight each of 10% of the final mark. There are two that are small multiple-choice tests where they also have to justify the chosen option. We dedicate 30 minutes to this. And two where in addition to the test they have to solve an exercise and justify the solution, this takes one hour.

At the end of the course, in the slot reserved by the School for the final assessment, students can repeat any of the tests they have taken during the semester. On this occasion, all the controls have a multi-response test part and an exercise.

The activities carried out during the semester (summaries, solving exercises, simulations ...) are assessed by the teacher at the end of the course if 80% of them have been completed on time. This assessment adds up to 10% of the final grade.

The most experimental part of the course is assessed with two laboratory exams (weighing 20% each) and a laboratory report grade (10%). Laboratory exams are conducted during a lab session and students must individually repeat a part of one of the experiments performed, write a small report with the results and answer some questions. The grade of the laboratory reports (10%) is proposed by the teacher at the end of the semester based on the reports delivered and the work done by the student in the laboratory sessions.

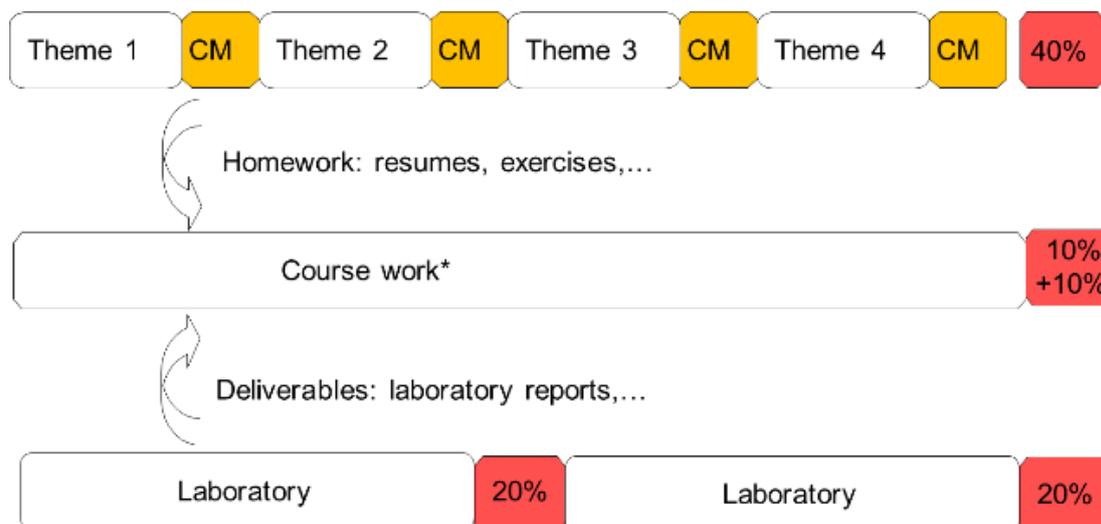


Figure 1.- Diagram of the assessment

We have tried to design an evaluation system that manages to engage the students in a continuous work from the beginning of the subject and until the end, some of the elements taken into account are (Armengol, 2007):

- Give opportunities to students to pass the subject until the last day.
- Not to eject students from the course until the end.
- Do not permit a student to pass the subject until the end.
- Give them the appropriate workload.
- Keep students informed of their performance
- Engage them in the course (hear their opinions, take them into account,...)
- Explain why the course is active.

▪ ...

3 Gaming

So far we have done gamification experiences like quizzes in class with electronic platforms, leaderboards of the homework,... which have shown us that students have an extra dose of motivation to participate in these activities.

The challenge of the new innovation project is to work on game-based activities in order to achieve deeper learning.

Although the variety of experiences and theories on which the games are based are very diverse⁷, we have set out to better develop the possibilities of game-based learning by redesigning the simulation activities that students carry out from the principles of McGonigal (2011) so that they are games from which they cannot escape without learning. The activity we found most appropriate to achieve this goal was a sequential escape room (Veldkamp, 2020). The simulation activities have been included in an escape room where students play in groups and to advance in the game they have to solve an enigma using the knowledge developed in the subject. As McGonigal proposes, the escape room seeks to have an epic mission, a clear goal, immediate feedback and another opportunity to prove it, and a positive social dimension.

3.1 The escape room

The escape room is a challenge: Students get on the train to come to the School (located in Terrassa, a city near Barcelona) and just as the train starts moving they hear a message from the driver that today the train will not stop in our city!!! "Just today my teammates have the most important commitment of the whole degree!!!". Students must advance on the train wagons until they reach the locomotive where the driver is to inform him that he must stop the train so that his classmates can come to school to carry out the most important activity of the year (Epic Mission). To cross each wagon (clear goal) the reviser asks them some questions that they must solve. In each car, the questions are on one of the topics of the subject and they can run some simulations to solve the problem. The questions you ask them are small exercises with multiple-choice options. At the end of all the questions in the wagon, they receive feedback on the result (immediate feedback) and if they have not answered all the questions correctly, they can try again (another chance to prove it). The game is played as a team (social dimension) and cooperation between team members is encouraged. They have one hour to complete the game, which is the train journey time.

3.2 The evaluation of the experience.

To evaluate the experience, we have added some questions to the traditional assessment surveys of each subject. Thus, having all the members of the team who participate in different subjects with different studies run the same questions, we can easily make comparisons.

The questions we propose to ask are:

Statement	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
The game has been a motivation to start working on the subject	1	2	3	4	5
The game has engaged me to practice more	1	2	3	4	5
I have enjoyed learning through play	1	2	3	4	5
The game has helped me to acquire a deeper level of understanding	1	2	3	4	5
I like the fact that I could solve the problems at my own pace	1	2	3	4	5
Mention three positive aspects that you have enjoyed					
Mention three shortcomings or things that you would improve					

⁷ Valero, Miguel. <https://personals.ac.upc.edu/miguel/materiales/docencia/articulos/Gamificacion.pdf>

4 Preliminary results

Preliminary results of the survey are shown in Figure 2.

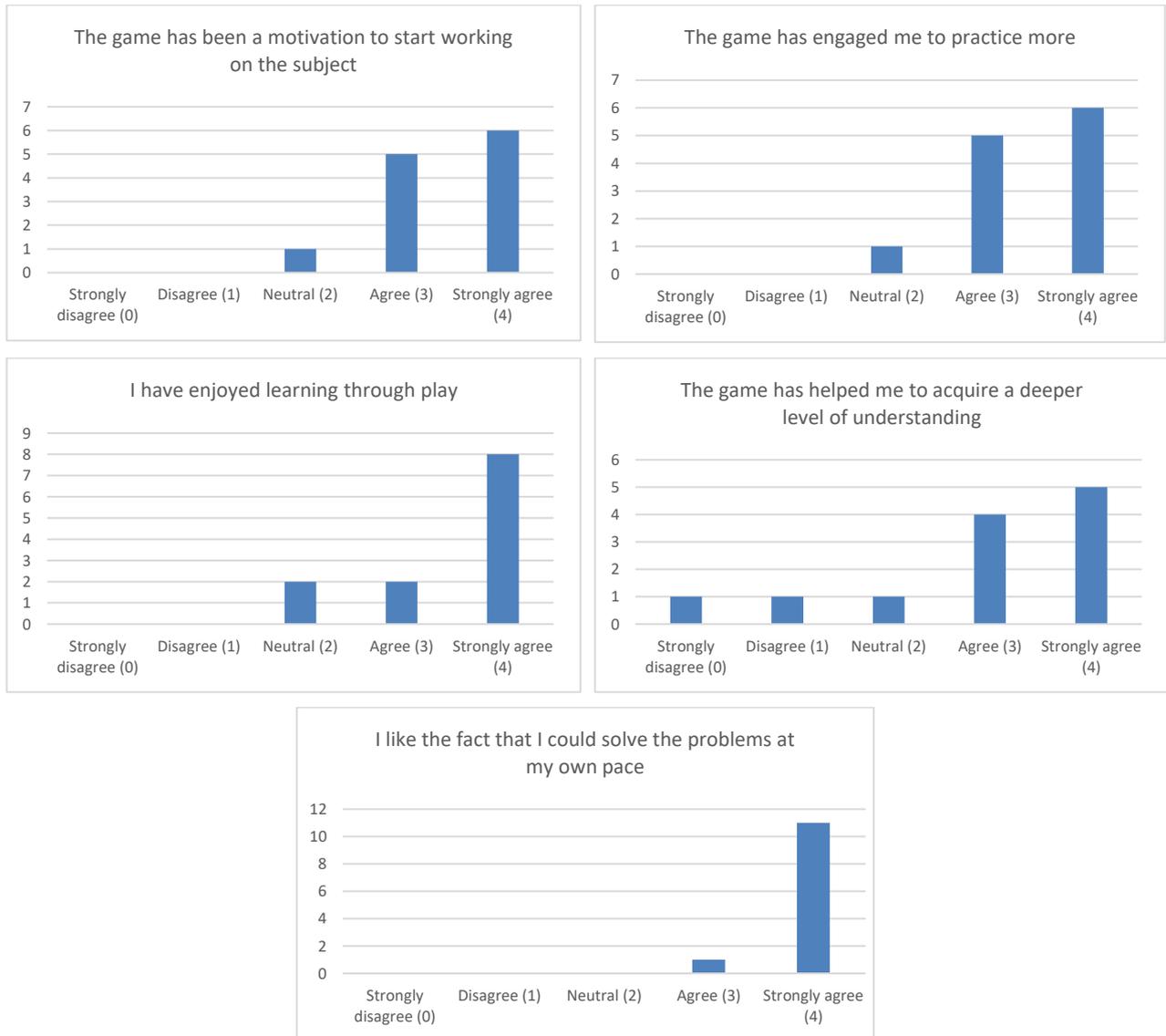


Figure 2.- Results of the survey. The vertical axis indicates the number of groups (each group having 3-4 students).

Access to the survey presented in the previous chapter was given once finished the escape room. Groups, the same ones who had participated in the game, answered it. There is only one answer per group. Each group consisted of between 3 and 4 students.

The processed results and discussion of the individual and joint surveys will be presented at the conference.

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Pair Teaching in Computer Graphics

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Abstract

Computer Graphics is a course commonly found on Computer Science and Computer Engineering undergraduate programs. There are some convenient points on teaching computer graphics in these programs: Computer-Generated Imagery in movies and videogames are relevant examples of applied engineering and science that students experience in their lives, and this can be a potential motivation factor for students to get engaged on learning; furthermore, Computer Graphics relies on several fundamental and complex mathematical concepts, that can also be applied in other science areas, being an opportune moment to cover and practice mathematical learning goals, all connected with a base on computer science. Learning Computer Graphics depends on developing and integrating skills on computer science and mathematics, therefore, a learning plan must cover both topics. However, it must be considered that students need to relate these topics, and this is the trick, since ideally professors need the knowledge and pedagogy in both areas. The strategy presented in this document was based on two professors, one mathematician and one computer engineering, planning, and teaching an elective undergraduate course on Computer Graphics. The course was based on active learning strategies by design, heavily focused on Project Based Learning through three projects starting from scratch, each week learning and implementing new features on the projects. Students must program in regular programming languages like Python, C++ and Javascript, and build up their competence in mathematics from basic math concepts. As a result, students were able to develop a scanline renderer, and a ray-tracing renderer without any graphical Application Programming Interface and finally a 3D web application based on ThreeJS. Although students had a perception of a demanding course, they were engaged on proposed activities during all semester, and were able to implement all important features on projects, often above expectation, showing evidence that learning objectives were achieved.

Keywords: Pair Teaching; Computer Graphics Teaching; Mathematics Teaching; Project Based Learning.

1 Introduction

The foundations of Computer Graphics rely heavily on mathematical knowledge. Therefore, the proposal of a Computer Graphics course that is not limited to the mere application of ready-made programming codes requires a plan on how Mathematics will be incorporated into classes. This plan becomes even more important when considering Computer Graphics as an elective course at the end of an engineering program, as mathematics is too much concentrated in the beginning of the program, usually in the first semesters. This is a scenario in which students show less readiness for the application of mathematical concepts in the context of the discipline. As a result, many students may have difficulties with basic mathematical content, such as vector operations.

However, the development of a didactic sequence that resumes the mathematical knowledge required by Computer Graphics may represent a great challenge. As a computer engineer or a computer scientist, this professor may not master the content and/or pedagogy of the mathematical area. Furthermore, a clear understanding of the mathematics track in the undergraduate program, will allow course professors to identify topics of mathematics that were covered in previous semesters of the course, having a better view on what should be reviewed and what could be an entirely new topic for students.

In order to deal with this problem a pair teaching strategy (Andersson & Lars, 2006; Ott & Meek, 2019; Burden, Heldal & Adawi, 2012; Zehetmeier, Bottcher & Brüggemann, 2018) was adopted: two professors of different areas working together throughout the course. It is important to point out that this is not a course split in two parts having professors teaching their topics, professors have discussed and defined learning goals, planned classes and activities, and evaluated projects all together. At first this strategy may appear less efficient since there are two professors at the same time in class, but improvement on learning was very evident.

This paper reports the experience of pair teaching in a Computer Graphics course offered as an elective in an Engineering program. The course, based on an earlier version lectured by only a Computer Engineering professor, was taught by two professors: a computer engineer; and a mathematician. The remainder of the paper explains: the main pedagogical strategies in chapter 2, selected results achieved on conducted course in chapter 3, and final conclusions on chapter 4.

2 Strategy

Working in pairs for teaching can bring several benefits, but a clear alignment must be established between lecturers to create coherent activities in classes. The starting point for achieving this alignment was the plan and material produced in the previous version of the course, to ensure that developing computer graphics skills and course goals were maintained and improved as possible. Then, the mathematical content required for each course phase was identified. The organisation of mathematical knowledge was defined at the beginning of the program, to define the most appropriate depth, order, and approach during the course. Another important constraint is that courses should follow an active learning pedagogy heavily based on project-based learning.

Since this course is taught at the end of the engineering program, bringing back fundamental mathematical concepts could be very challenging. In this case, the profile of students enrolled in the course was necessary to better design activities in the mathematical area. Usually, students are more interested in working on more advanced projects, and very often they rely on tools or applications that hide the complexity of development, in this case on mathematics and computer science, but since the beginning students were informed that this course would dig in the fundamentals of mathematics and low level programming.

Thus, weekly demands were defined in the projects, most of which involving some type of mathematical knowledge and applied computer science. During classes, students worked in pairs or trios, guided by handouts that addressed the content required in that week's delivery. In this way, the progress concretely observed in their projects was the main motivation for studying the mathematics involved.

An example of this strategy was the study of rotations by quaternions. The representation of a three-dimensional object rotation by quaternions is a technique commonly used in computer graphics, since it avoids known problems of Euler's angles (Pletinckx, 1989). Its mathematical justification is based on the understanding of quaternions as a 4-dimensional space that contains complex numbers. More than just applying formulas to implement quaternion rotations in their projects, the proposed activities allowed students to have a real understanding of what they were doing in their programming code.

In addition to the weekly deliveries related to the projects, revisions were scheduled at strategic points in the course, which supported students to understand the big picture related to the procedures previously studied. These revisions were usually associated with the development of a complex case where students could check their understanding.

Three main projects were distributed during the semester that were further subdivided. The partial project deliveries have generally lasted a week, so that students could build their project and see some progress little by little.

2.1 Scanline Renderer

The first project was a conventional scanline renderer (Foley, van Dam, Feiner & Hughes, 1990). Students would initially implement an algorithm to identify 2D triangles and generate an image, but soon afterwards they would work in 3D, calculating the perspective view of a scene, calculating the lighting and traditional rendering resources such as anti-aliasing. Students had to develop from scratch using Python as a programming language. A skeleton code was provided by a git repository for them to follow the development and render some known sample scenes. The scanline render was designed to read X3D files (<http://www.web3d.org/>), what is a convenient format since it is open, well documented, and in text format, and all geometry can be parametrized.

The expected deliverables were:

- Render 2D colourful points, lines, and triangles
- Calculate perspective projection
- Render 3D triangles and triangle strips
- Rendering using super sampling
- Scene graph implementation
- Interpolate colours across triangles
- Texture map triangles
- Z-Buffer implementation
- Calculate illumination over triangles
- Render an animated scene

The deliverables were sometimes subdivided, and students were requested to implement and test their code with the examples. Balancing the level of complexity for the week's task was not simple since previous experience did not take into account the extra care with mathematical teaching.

2.2 Ray Tracer

The second project was a ray tracing renderer, for which Peter Shirley (2020) books were used as a basis. Initially students should implement the basics of the algorithm, following the book. The suggested language for this renderer was C++. In the sequence, challenges were proposed for the implemented ray tracing algorithms that students should fulfil. Ray tracing algorithms have a different strategy from scanline algorithms, but some mathematical concepts are reused, and some entirely new mathematical concepts were brought on this project.

One of the biggest differences from the first project, was the fact that ray tracing algorithms expect implicit representation of geometries, for instance, a sphere centred in the origin is represented by: $x^2 + y^2 + z^2 = r^2$. This creates several new challenges for students that must adapt their mindset for this new project proposal.

The main deliverables were:

- Implement a new implicit geometry (like cylinders, torus, among others)
- Develop a texture based on some noise function
- Texture map a 3D object

The time for students to implement the basics of the renderer were 4 classes (classes are two hours long), although the algorithm documentation was very complete, students should take care of small details in order to compile the code successfully.

2.3 3D Web Project

The third and final project was the development of a theme free 3D application for web browsers. Students should implement a 3D scene using the ThreeJS 3D web API (<https://threejs.org/>) which is convenient as it does not depend on any specific platform, like Windows or MacOS. At that moment students were very creative, with curious scenes created.

Students were free to choose direction, but they must discuss with professors next steps, defining an adequate level of complexity for each intermediary delivery. This project management strategy was based on agile methodologies (Fowler & Highsmith, 2001), where professors would act as Product Owners.

3 Results

The results presented are based on the comparison to the previous version of the Computer Graphics course. The last version, in which pair teaching was adopted, allowed a greater advance both in programming and in mathematical learning evidenced by the quality of project deliverables. In the previous version, students did not progress as fast as expected because they had to review the mathematical concept by themselves without

proper support. For example, there was no time to discuss rotations with quaternions in the first version, as students were struggling with vector operations in describing rotations. And despite the denser content in the last version, students were able to fulfil most of the expected learning goals and tasks.

Another important point is how difficult it was for students in the previous version to connect what they did learn in math and how to use it on a real computer graphics application. Apparently, this connection was more natural for students that took the course with pair teaching.

These courses (last and previous versions) were taught at Insper (Soares, Achurra, & Orfali, 2016), and the educational institution collects blind feedback from students. Both courses were well evaluated by the students. Just, in the last version of the course, students pointed out that the course was more demanding than a regular elective, but this did not affect their motivation, and learning was enhanced due new activities planned.

There were some complaints about specific maths assignments charged at the beginning of the semester. Based on feedback, these deliverables have been discontinued, and content has been incorporated in project deliverables.

For the first part of the course, they were challenged to acquire all the expertise to develop a scanline rendering. Figure 1 and Figure 2 show some results from student's projects.

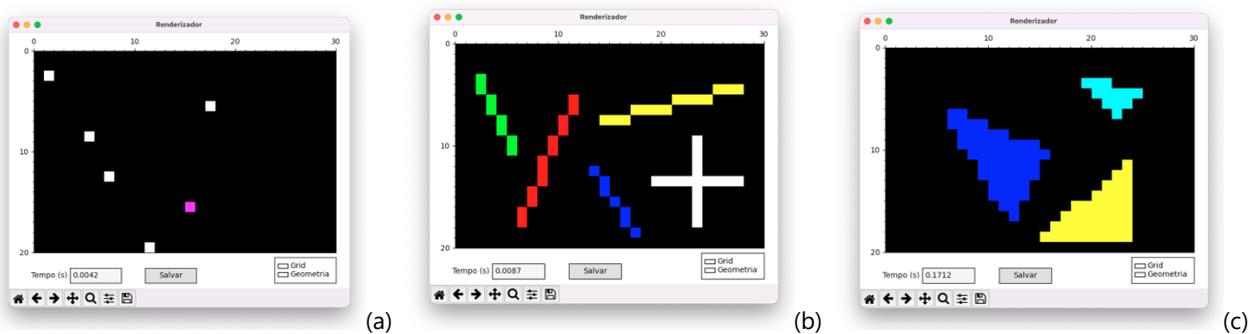


Figure 1. 2D render of points(a), lines(b) and triangles(c).

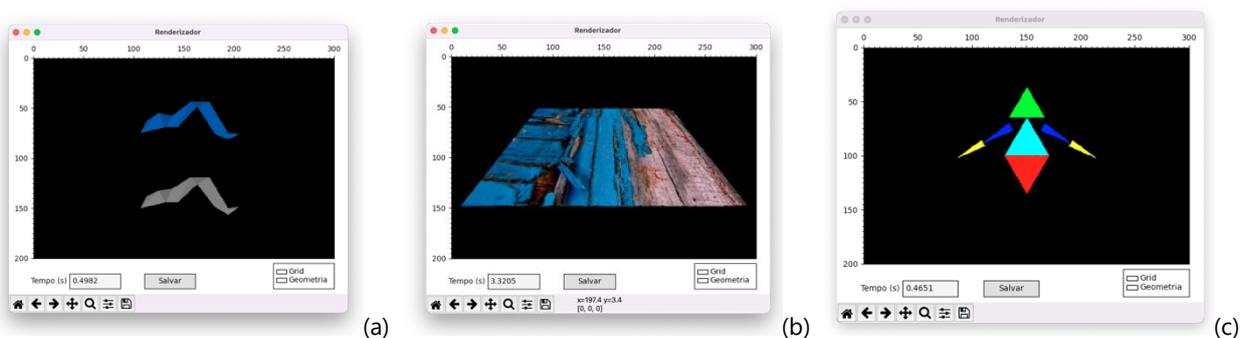


Figure 2. 3D render of triangle strips (a), texture maps (b) and scene graph (c).

Although the requested project was the same for all students, it is possible to see small details different from project submission to submission. One noticeable difference between each project submission was the time necessary to render 3D scenes. Rendering time was not a point for assessment, but some students did work on improving the performance of their algorithm, and at the end some complex scenes took a few seconds to render in some projects and in other projects took some minutes. This was also important for students to understand that rendering is a complicated process, and depending on the way you implement, algorithm run time and space requirements can exponentially grow as the input size grows (Chivers & Sleightholme, 2015).

The second project was based on a well-documented ray tracer (Shirley, 2020). Students had to implement the traditional ray tracer and after implement some kind of improvement for the system. Some of the implementation's results are presented in Figure 3.

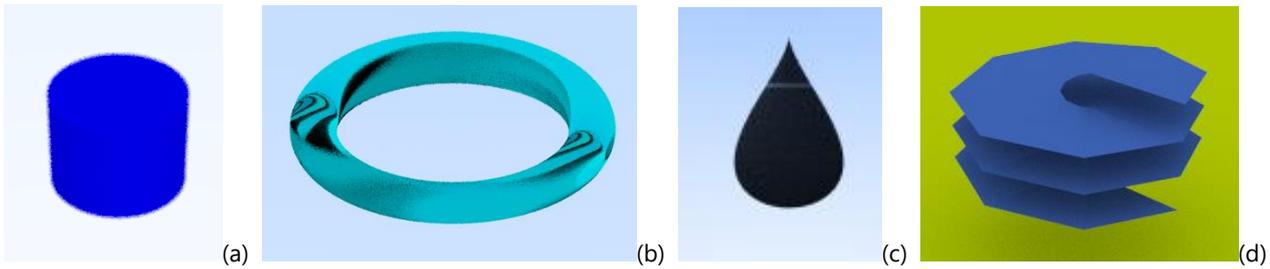


Figure 3. Ray tracing render of cylinder (a), torus (b), drop (c) and spiral (d).

Shirley's book (Shirley, 2020) implementation shows only how to render a sphere, this is a convenient geometry for learning, but students were challenged with other geometries. In the end this was a complex task for students since it is possible to see some problems in most of the delivered results. We were expecting a cylinder in Figure 3 (a), although it is possible to recognize it, the calculation for surface normal is not correct, if normal were correctly calculated it would be possible to identify the interior part. Figure 3 (b), shows a torus that has a very complex equation to solve; students did an excellent job, but it is possible to visually confirm that normals were not well calculated. Figure 3 (c), shows a 3D drop, and again normal were not perfect and there is a small detail failing some render lines at the top of the drop. Finally, in Figure 3 (d) there is a spiral, the most complex geometry, students were able to correctly calculate normals, but they have to adapt the spiral equation.

As a second part of the second project, students were challenged on developing different textures, using noise functions, in particular Perlin Noise (Perlin, 1985), to create different materials. Figure 4 shows some results implemented by the students.

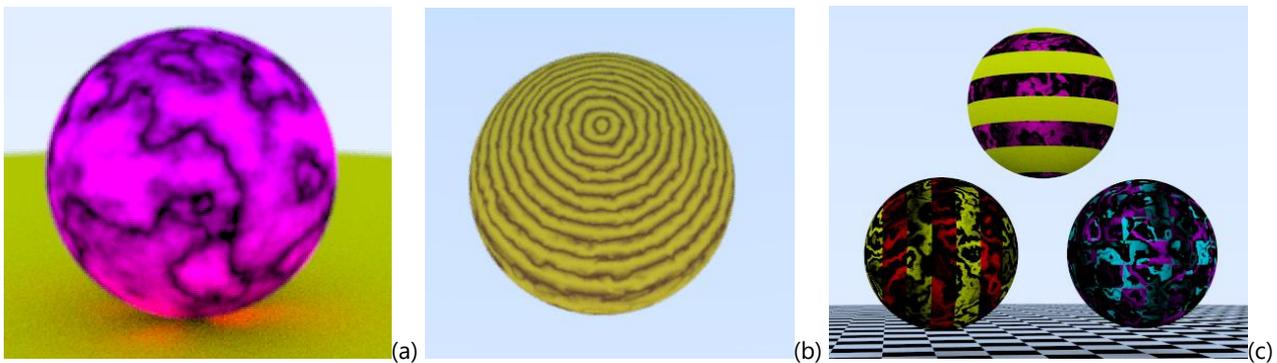


Figure 4. Materials created for a ray tracer using Perlin noise function among other techniques.

Students were very creative in creating new textures exploring mathematical functions. Professor's perception was that students enjoyed developing this creative work.

At the end, students had a complete free 3D project. This was an opportunity for students to create a more complex project and publish on the web for anyone to see. Students learned how to use a scene graph, in an advanced API (Application Programming Interface), in the case ThreeJS. Figure 5 shows some results from student's projects.

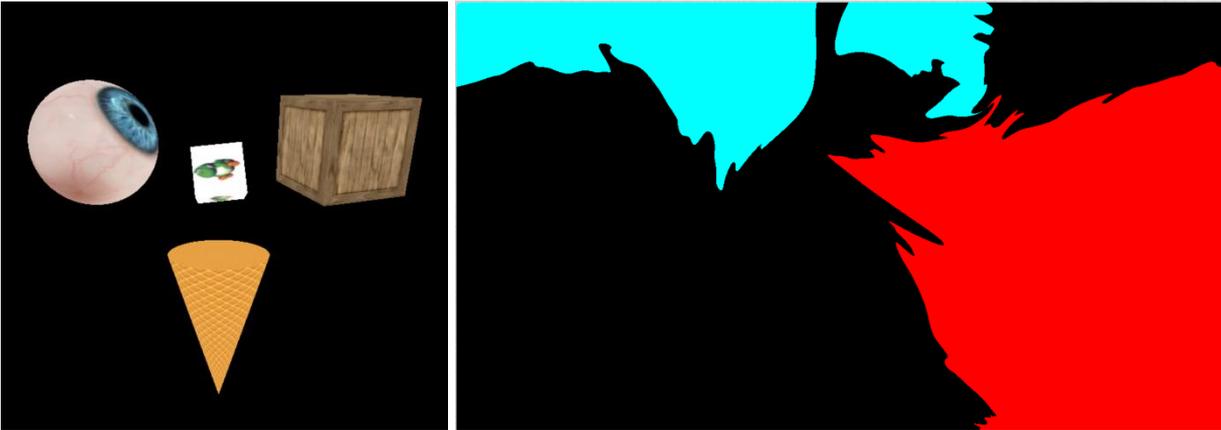


Figure 5. Sample images of theme free computer graphics web project.

There were several deliverables for the students during the semester, and students were a little concerned about the complexity of the topics in the course, and one student decided to leave the course. The first deliverables had an extremely high quality, and students were giving their best to accomplish the proposed challenges as best as they could. During the entire course topics had about the same level of complexity, but students start to burnout, and the deliverables were not so complete as used to be in the first part of the course. As professors start to notice that students were not delivering project with the same quality, they decided to slow down a little. In a future version of the course, professors should better balance how difficult are the projects and better track if students are burning out.

3.1 Difference between course versions

The most noticeable difficulty some students had in previous course versions was in vector operations. The course was not advancing as expected since skills in geometry transformations were necessary for the course and these are based on vector operations. In previous versions of the course this problem was tackled in a corrective way, as students started to struggle with vector operation, support classes were created. In the last course version, with two professors, vector and other mathematical topics were treated in a preventive way, but instead of a pure revision, students were oriented on how to learn the topic, with general exercises, readings, videos and even lectures to support students for their projects.

At the end, students could deliver projects with more details and quality, for instance in previous versions, the fourth part of the first project was not even published for students, since some support classes were necessary, and the original plan was delayed. On the second project in previous versions, only basic resources of the ray tracer were developed and in the last version not only the basic resources were implemented as some complex routines were also incorporated.

4 Conclusion

Having two professors on this computer graphics course, one mathematician and one computer engineer, allowed students to better discuss and learn several details in mathematics and computer science that otherwise would not be so practical. Classes were planned in an active way where students could discuss with professors graphical and mathematical techniques, also having studio time (that is time slots for developing their project in class) allocated for regular activities and project development.

There was a clear improvement on projects quality comparing the pair teaching version with previous version of the course with a single professor. In the pair teaching edition, students were able to implement more graphical techniques, and the quality is also noticeable. In the first edition, small mistakes on algorithms and math routines lead to imagens with some strange artifacts, what was not often noticeable in the pair teaching version.

The course has yet a lot of opportunities for improvement: for instance, in the first project a better sequence of topics can be used, in the second project the high dependency of an external book is not creating enough

opportunities for learning, and additional motivation for the final project can lead to better projects, what by consequence should improve learning.

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Application of Project-Based Learning and Lean tools in a machining area of a welding industry

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Abstract

This paper has the objective of applying Project-Based Learning to propose improvements and measure the movement times in the machining area, using the Value Stream Mapping and Spaghetti Diagram as tools. This was a study developed by Graduation Students in Production Engineering of the Fluminense Federal University in partnership with a welding industry. The methodology can be classified as exploratory and descriptive, applying the bibliographic method to understand concepts related to machining, lean manufacturing, Value Stream Mapping (VSM) and Spaghetti Diagram, and it is also a case study, using the machining area of a welding industry as an analysis unit. The practices of project management recommended by the PMBOK Guide from Project Management Institute (PMI) were used, as well as the Project-Based Learning (PBL) methodology to drive the study in terms of research and application in the analysis unit. The activities of the machining area were mapped through the Value Stream Mapping and Spaghetti Diagram in order to identify the non-productive movements and time. Considering the results from the bibliographic search and the process mapping, alterations were proposed in the layout and order of activities and also, removed the ones that do not add value to the product. The improvements suggested to the welding industry were implemented and resulted in a reduction of 33h, equivalent to around EUR 5.000.

Keywords: Project-Based Learning; Lean Manufacturing; Value Stream Mapping; Machining.

1 Introduction

When a project is presented to students simply “because they will need the knowledge in the future” or “because they will need to understand it for the next subjects”, there is no natural engagement and motivation required for students to feel challenged to solve the problems of a given situation (LARMER et al., 2010). In this way, an approach which offers the investigation of authentic and real problems is needed.

Project-Based Learning (PBL) is a student-centered, teacher-facilitated learning methodology where students search for knowledge by asking questions. Such questions guide the research, which is supervised by the professor (BELL, 2010). In addition, PBL can be considered as a model that organizes learning around projects, (THOMAS, 2000).

In this context, the paper was developed by Graduation Students in Production Engineering from the Fluminense Federal University (UFF) of Rio de Janeiro, Brazil, with a company in the welding industry. Considering that there is downtime and non-productive hours in the machining sector, the students defined the central question as “How to reduce downtime in a machining sector through PBL using Lean Manufacturing as the main driver?” The students defined as specific questions “How does the machining process work?” and “Which is the most appropriate Lean tool for reducing downtime?”. Both questions aimed to answer the central question.

This paper has the following structure: first, the bibliographic research will be addressed. Next, the methodological description for the academic project is presented and finally, the results and conclusion.

2 Bibliographic research

This topic will present the results of the bibliographic research done to provide theoretical basis to all improvements suggested to the welding company.

2.1 Machining

According to Davim (2008), "machining is the broad term used to describe the removal of material from a workpiece". Also, it is called an operation that gives the part shape, dimensions and surface finishes by removing the material in the form of shavings.

Machining has two types of processes, conventional and unconventional. In conventional processes, cutting operations use mechanical energy to remove material from the part. In unconventional machining processes, cutting operations use other forms of energy, such as thermoelectric power (MACHADO et al, 2015).

With the technological advances in machine tools, there was the emergence of automatic machines, and soon after, of Computer Numerical Control (CNC) machines. According to Silva (2014), CNC lathes transmit information in the form of movement by activating and deactivating the machine tool's features according to the sequence that has been programmed without depending on the assistance of an operator.

The question "How does the machining process work?" is answered through this topic, at the same time it helps the students understand the process in the analysis unit that relies on both conventional and CNC machining. As the central issue is focused on reducing downtime in this area, it is important to understand how the steps flow and which activities are essential and which are not.

2.2 Lean Manufacturing

According to Touriki et al (2021), Lean Manufacturing can be seen as "an amalgamated sociotechnical method aspiring to reduce waste by minimizing the manufacturing variations". In Lean view, waste can be defined as anything that does not add value to the product (GUPTA & JAIN, 2013).

The 3 M's (Muda, Mura and Muri) are Japanese terms related to different types of waste. The first, Muda, refers to uselessness and has 8 types, according to Womack and Jones (2013): excess production, waiting, unnecessary transport or movement, process excess or incorrect process, excess inventory, unnecessary movement, defects and misuse of personnel. According to Santos et al. (2011), Mura is waste related to lack of balance and Muri is waste related to overload.

Lean Manufacturing has several tools, which are applied in companies to reduce waste. Matt et al. (2013, p. 423) developed the matrix presented in Figure 01.

Type	Lean Production methods	micro	small	medium	large
Machinery and equipment	Low Cost Automation	○	●	●	●
	OEE Overall Equipment Effectiveness	○	●	●	●
	Preventive Maintenance	○	●	●	●
	Setup Time Reduction (SMED)	○	●	●	●
	Total Productive Maintenance	○	●	●	●
Material flow and layout	Cellular Manufacturing	○	●	●	●
	First in first out (FIFO)	○	●	●	●
	One-piece-flow	○	●	●	●
	Simulation software (e.g. MatFlow)	○	○	●	●
	Optimization of the supply chain	○	●	●	●
Organization and staff	Value Stream Mapping	○	●	●	●
	Work station design	○	●	●	●
	SS	○	●	●	●
	Autonomous work groups	○	●	●	●
	Benchmarking	○	●	●	●
Production planning and control	Ideas Management	○	●	●	●
	Job rotation	○	●	●	●
	Lean Office (Administration)	○	●	●	●
	Kaizen (CIP-Meetings)	○	●	●	●
	Standardisation	○	●	●	●
Quality	Just in Sequence	○	●	●	●
	Just in Time	○	●	●	●
	Kanban	○	●	●	●
	Line Balancing and Muda reduction	○	●	●	●
	Milkrun	○	●	●	●
Quality	PPS Simulation software	○	○	●	●
	Economic (optimal) lot size	○	●	●	●
	Visual Management	○	●	●	●
	FMEA	○	○	●	●
	Poka Yoke	○	●	●	●
Quality	Quality Circles	○	●	●	●
	Quality Function Deployment	○	○	●	●
	Six-Sigma	○	○	●	●
	Statistical Process Control (SPC)	○	●	●	●
	Supplier Development	○	●	●	●
Quality	Total Quality Management	○	●	●	●
	Zero Defect (Jidoka)	○	●	●	●

Figure 1. Types of Lean Manufacturing tools related to the organization site. Source: Matt et al. (2013, p. 423).

Considering that the company used as a case study is characterized as medium-size and the specific question “Which is the most appropriate Lean tool for reducing downtime?”, the tools listed in Material flow and layout type were analysed. Value Stream Mapping was selected as the most appropriate Lean tool for reducing downtime because is conceptualized in a critical analysis of material and information flows along the value chain, which makes it possible to highlight waste and opportunities for elimination thereof (ROTHER & SHOOK, 2003).

Typically, the Spaghetti Diagram is used in conjunction with Value Stream Mapping, due to the fact that aim of tracing a path taken by materials or information in a specific layout (Tapping & Shuker, 2010). In this way, the diagram allows the visualization of displacements and unnecessary efforts, showing and mapping the waste of movement and transport. Therefore, both VSM and Spaghetti Diagram were used.

3 Methodology

In the following topics, the research classification, analysis unit, procedures for both collecting data and bibliographic research as well as the PBL approach will be presented.

3.1 Research classification

The research can be classified as exploratory and descriptive, providing greater familiarity with the problem to make it more explicit and describing and establishing relationships between variables, respectively (GIL, 2002). Also, this work is a case study, which is the most appropriate strategy when “how” and “why” questions are defined about a set of events and something the researcher has little or no control over (YIN, 2015).

3.2 Analysis unit

The analysis unit is a German multinational in Petrópolis - RJ characterized by its productive activity focused on a cutting and welding portfolio. The company produces welding torches, air or water cooled, for use in manual, semi, or fully automated operations. The focus of this paper was in the Machining Sector, which is responsible for manufacturing components used in assembling of welding torches.

3.3 Procedures for collecting data

The students used three main sources of evidence. First, interviews with Machining employees to understand the process flow and help to answer the question “How does the machining process work?”. Also, interviews with the Managing Director and Industrial Manager to guide the students in prioritizing solutions.

Second, company documents and databases such as layout drawings and Work Orders, both to comprehend the process flow and answer the central question. And finally, observations made by the students during technical visits to the organization. These visits aimed to time each activity of the process flow for VSM.

3.4 Procedures for bibliographic research

The students divided the research into five steps: (i) searching literature on platforms through key words; (ii) organizing the articles by chronological order of citations, alphabetical order of authors and article coverage; (iii) selecting and prioritizing by choosing the most cited authors in the theme; (iv) reading and emphasizing the most relevant parts; and finally (v) writing, showing how the authors studied correlated with the topic of the research, in this way not simply summarizing their work. (TURRIONI & MELLO, 2012).

3.5 Stages for applying the PBL approach

The practices of project management recommended by the PMBOK Guide from Project Management Institute (PMI) were used for applying the PBL approach and its stages are described in the following topics.

3.5.1 1st stage – Definition of problem-situation and elaboration of the Project Opening Term

The problem-situation was defined together with the company and the questions were defined in conjunction with the professor to guide their research. According to Larmer et al (2010), a good guiding question captures the heart of the project in clear language and is related to the content that the teacher wants the student to

learn at that moment. As a deliverable of this stage, the Project Opening Term was elaborated containing the justifications, objective, benefits, project leader and team, sponsor as well as estimated deadline.

3.5.2 2nd stage – Elaboration of the Project Management Plan

The students prepared the Project Management Plan, which is contained the number of visits in the analysis unit and deadlines to answer the questions. For Thomas (2000), a PBL project should not be carried out under controlled conditions, in laboratories, limited by professors or by a script. To be considered a PBL project, there must not be a pre-determined product nor a pre-defined path to follow, students spend more time without professor supervision, rather having autonomy to seek the necessary knowledge and skills. Therefore, the action plan should be defined only as a support for the students during the project.

3.5.3 3rd and 4th stages – Project execution and control

The execution was done with the professor’s support, being necessary for students to acquire the required knowledge and understanding to define possible solutions and evaluate possibilities according to the literature and the context of the project. These stages aimed to respond the central question through the bibliographic research, interviews, company documents and database as well as visits to the organization. Also, it aimed to elaborate the VSM and Spaghetti Diagram.

3.5.4 5th stage – Project ending

In the Ending stage, the project’s product is publicly presented not only to the professor, but also to a relevant audience – in this case, the company stakeholders. In this way, the meaning of the entire project-based learning process is reinforced (LARMER et al., 2010).

4 Results

Next, the results of the activities described in Methodology are presented. This topic was structured in two parts: analysis of the problem situation and proposals for improvement.

4.1 Analysis of the problem-situation

The scope of this study is the processes performed before and after machining a part and not the manufacturing process itself. The students divided the problem-situation into three processes and analysed its current scenario. The bibliographic research, interviews and questions guided all the improvements proposed by the students.

4.1.1 Current scenario – Value Steam Mapping of WIP shelf process

Work in-process (WIP) parts correspond to assembled items that still need to be machined. The activities in the process flow are represented by boxes in VSM as shown in Figure 2. In VSMs, all the cycle times (CT) were timed by the students during visits to the organization and the order of activities was collected through the interviews.

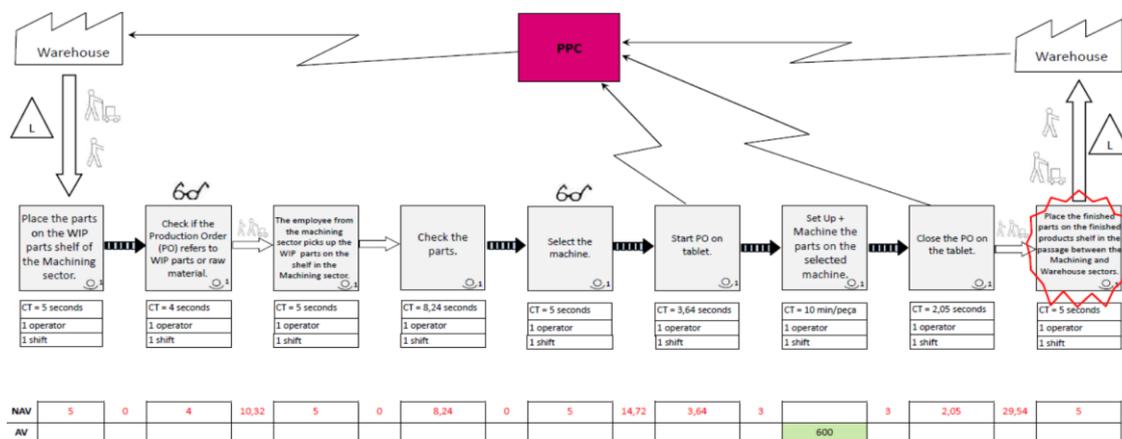


Figure 2. VSM of WIP shelf process – current scenario.

According to Figure 2, the last activity highlighted in red means that there is an opportunity for improvement. In current scenario, the employee takes the parts to the finished products shelf outside the Machining sector. The students proposed to place this shelf within the sector to reduce movement time.

4.1.2 Current scenario – Value Steam Mapping of raw material shelf process

The raw materials used in the Machining sector are brass or copper bars that are stored inside the Warehouse. Focusing only on the highlighted activities in Figure 3, after checking if it's a WIP or raw material Production Order (PO), the employee waits for the PO booking in the Warehouse. The students proposed this booking process to be after finishing the PO. And the last activity was covered in the previous topic.

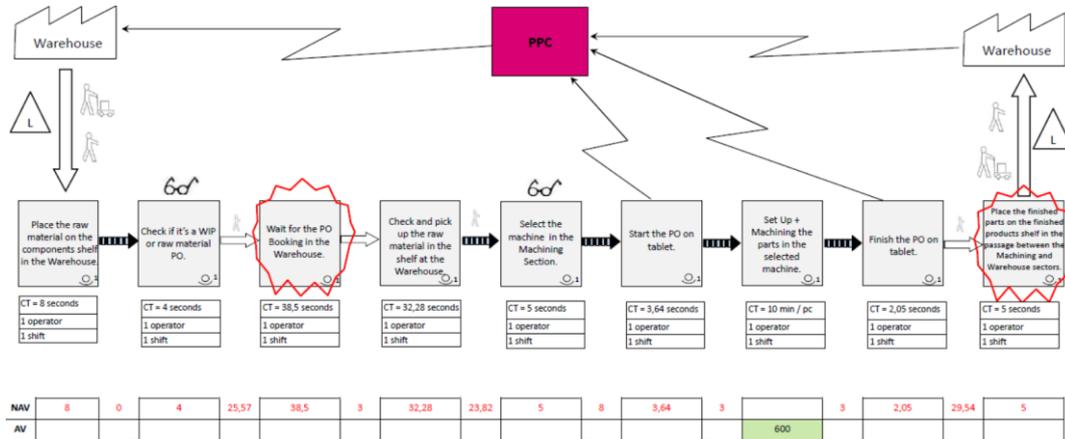


Figure 3. VSM of raw material shelf – current scenario.

Removing the waiting for the PO booking, the students followed the Lean Manufacturing most important principle of reducing waste and consequently, downtime. It is important to emphasize how valuable is the PBL projects, due to the fact that the students are able to apply the knowledge learned during bibliographic research.

4.1.3 Current scenario – Value Steam Mapping of exchange of shavings barrels process

Shavings are produced during the machining and in this case, shavings coming from the Computer Numerical Control (CNC) Turning Center will be analysed. The students proposed removing the first two activities highlighted in red, because the pallet trucks and the barrel area should be within the Machining sector, avoiding movement time between areas.

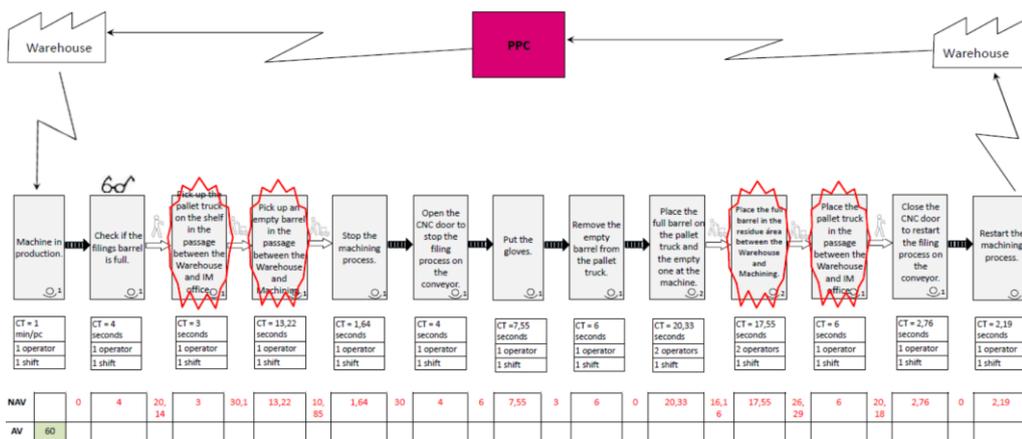


Figure 4. VSM of exchange of shavings barrels – current scenario.

According to Figure 4, the activities of placing the full barrel and pallet truck in the appropriate area should be done after restarting the machining process. Then, the parts would continue being manufactured while the employee does these activities.

4.1.4 Current scenario – Spaghetti Diagram

The Spaghetti Diagram was built to analyse the movement and trajectory of employees in the Machining sector when they need to pick up a tool or instrument that helps them in machining parts. In it, the coloured lines represent the trajectory of the employees starting from each machine and going to each cabinet. These movements can be seen in Figure 5.

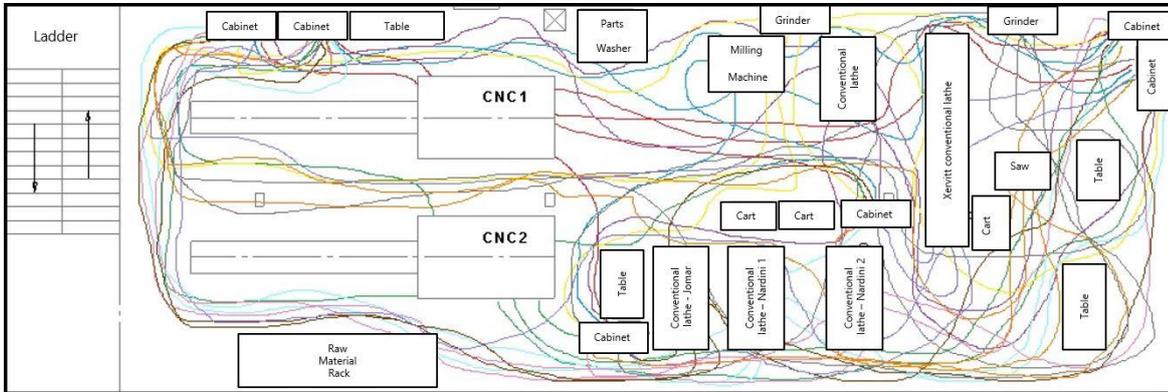


Figure 5. Spaghetti Diagram – current scenario.

It was identified that the employees needed to move around a lot to find the instruments and tools that were scattered around the cabinets in the Machining sector. Therefore, it was proposed creating a tooling and instrumentation room. With this, the employees’ trajectories would start from their machines to a specific place, not needing to go around the entire sector looking for instruments and tools.

4.2 Improvements proposal

After analysing the current scenarios of all processes selected for this study, improvements were proposed to the welding company as previously showed. This topic is divided into two parts: compare the results from both current and future VSMs and present the Spaghetti Diagram after the tooling and instrumentation room.

4.2.1 Future scenario – VSM of all processes

From the comparison of data from the Current and Future Value Stream Maps, it was possible to quantify the gains obtained by the proposed improvements suggested for the sector. The process efficiency calculation is obtained by dividing the time that adds value to the process by the lead time. Therefore, the following values shown in Table 1 were obtained.

Table 1. Comparison of VSM results – current and future scenarios.

Process	Criteria	Current	Future	Percentage
WIP shelf	Cycle time	637,93	637,93	0,00%
	Value added time	600,00	600,00	0,00%
	No added value time	98,51	84,42	14,30%
	Lead time	698,51	684,42	2,02%
	Process cycle efficiency (%)	86%	88%	2%
Raw material shelf	Cycle time	698,47	637,69	8,70%
	Value added time	600,00	600,00	0,00%
	No added value time	194,40	88,83	54,31%
	Lead time	794,40	688,83	13,29%
	Process cycle efficiency (%)	76%	87%	12%
	Cycle time	147,69	121,02	18,0%

Exchange of shavings barrels	Value added time	60,00	60,00	0,00%
	No added value time	250,41	93,70	62,58%
	Lead time	310,41	153,70	50,48%
	Process cycle efficiency (%)	19%	39%	20%

All the results presented on Table 1 are regarding one execution of each process. Together with the Machining Supervisor during the interview and according to the company's database, it was identified how many times each process is done weekly and with this, the annual gain in hours was calculated, which can be used by the employee in other activities that add value to the organization.

Table 2. Annual gain in hours.

Criteria / Process	WIP shelf	Raw material shelf	Exchange of shavings barrels	Total
Estimate of process execution / week	20	15	4	39
Estimate of process execution / year	960	720	192	1.872
Annual gain (h)	3,76 h	21,12 h	8,36 h	33,24 h
Value of man-hour (EUR)	EUR 151,00	EUR 151,00	EUR 151,00	EUR 151,00
Reduction in costs (EUR)	EUR 567,76	EUR 3.189,12	EUR 1.262,36	EUR 5.019,24

As it can be seen on Table 2, all the improvements would result in a reduction of 33,24h annually, which is equivalent to a cost saving of EUR 5.019,24. These hours can be invested in activities that add value to the product, considering that all proposals were implemented.

4.2.2 Spaghetti Diagram after improvements

After implementing the tooling and instrumentation room and aiming better visualize the movement flow in the new layout model, a future Spaghetti Diagram was prepared.

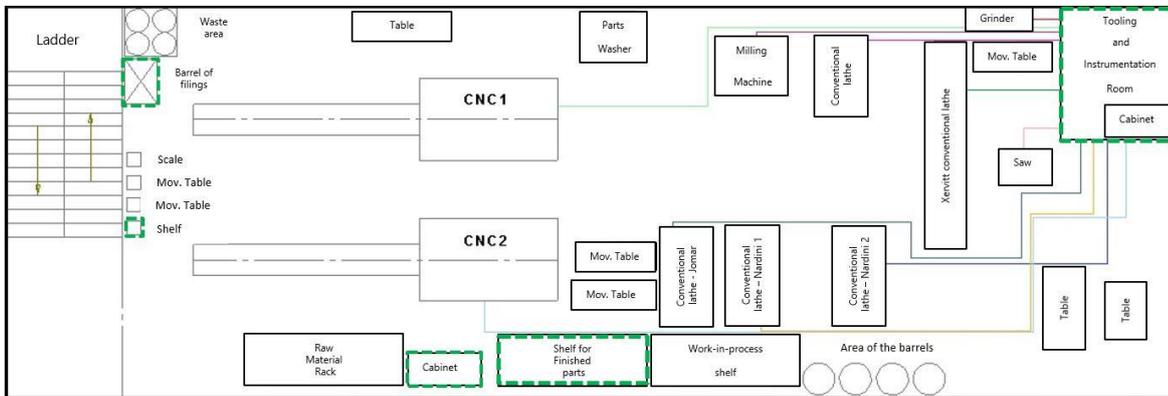


Figure 6. Spaghetti Diagram – future scenario.

Comparing both Figures 5 and 6, the main reason to significantly reduce the movements inside the Machining sector is the creation of a tooling and instrumentation room. The green highlights are the layout improvements.

5 Conclusion

This paper aimed to conduct a project through PBL by applying the Value Stream Mapping and the Spaghetti Diagram in the machining process, having as central question "How to reduce downtime in a Machining sector through PBL using Lean Manufacturing as the main driver?" The students were oriented by the professor to define specific questions to help answering the central one: "How does the machining process work?" and "Which is the most appropriate Lean tool for reducing downtime?".

The PBL methodology divided the project into five stages, where the first one defined the problem-situation with the analysis unit and helped the students to prepare the questions that would guide their learning process. In the second stage, the students planned the activities within the organization and bibliographic research in terms of deadlines.

In the third and fourth stages, they had to answer the questions. For “How does the machining process work?”, the students learned through the bibliographic research, interviews with the Machining employees and visiting the company. And for “Which is the most appropriate Lean tool for reducing downtime?”, by searching in literature and interviewing the Managing Director and Industrial Manager, the Value Stream Mapping and Spaghetti Diagram were selected as the most appropriate Lean tools for reducing downtime.

As a result of elaborating the VSM of each process, it became possible to identify and eliminate some activities that did not add value to it, reducing the lead time of the processes. Regarding the Spaghetti Diagram, it helped to define an ideal layout for the machining sector, eliminating unnecessary employee paths. With the suggested improvement proposals, there was an annual reduction of 33 hours in activities, which can be used in a better way by the employee, performing activities that add value to the process and that optimize the productivity of the organization. These 33 hours are equivalent to EUR 5.019,24.

Finally, the fifth stage of presenting the project, it is clear that the central question “How to reduce downtime in a machining sector through PBL using Lean Manufacturing as the main driver?” was answered. Not only by following the PBL staged, applying the methodology and answering the specific questions, but effectively reducing downtime in an average of 50%. This result shows how important is for students in participating in academic PBL projects and in partnership with industries, because it gives students the experience of how to solve real problems within an organization. Another important benefit of this type of project is being able to guide students in determining the area of Production Engineering that they most identify with.

In addition, through the study, it was possible to apply the knowledge obtained in the academic environment and participate in the implementation process of the proposed solution. In this sense, students had the opportunity to live experiences in an industry, while still in the academic period, thus providing learning outside the university, a balance between theory and practice.

This paper was also very beneficial for the students in three main aspects: first, the approach to the academic environment, in writing an article and looking for the best references on the subject; the deepening of the vision through the process, increasing criticality and the search for better solutions that fit the specificity of the process and, finally, the possibility of understanding how the company and the job market work.

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An Approach to Encourage Girls' Protagonism in Exact Sciences and Engineering

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Abstract

The 21st century has come highlighting the world's concerns regarding competitiveness in face of new demands arising from accelerated technological advancement and, on the other hand, with inclusion, sustainability and quality of life. Therefore, gender equity in STEM fields has also become part of the goals of the 2030 agenda for sustainable development, with the aim of building a less exclusionary world. Faced with this urgent need to design a more inclusive future, several approaches have been proposed to attract girls to the exact sciences and engineering using active learning strategies and valuing the protagonism of these students in their school environment. In order to do so, a group of six ninth grade girls were invited to participate in the pilot project Accelerating Girls in Elementary School, conducted by undergraduate students in the exact sciences and engineering, and accompanied by professors from the school and from the University of Brasilia. In it, the Elementary School students were organized into a team to propose and present STEM hands-on practices, according to curricular contents, to their own class. The steps for designing such activities include weekly meetings for the development of the flipped classroom, quizzes and hands-on activities. Aspects and outcomes related to this process are described and discussed based on the literature, motivating reflections on strategies used to develop skills and competencies in STEM with young girls.

Keywords: Active Learning; Elementary School; Girls Protagonism; STEM Education.

1 Introduction

In recent years, the rapid technological development, on a worldwide scale, has been causing movements in education and in the job market in search of greater female inclusion, since women were historically placed on the margins of this academic and professional space. Despite advances, education is still not universal and as gender inequalities are still significant, and a current worry, not only the girls access to a current school, but also the limitations they face in the academic environment, more specifically, is reflected in the low number of girls regarding STEM education.

In line with current demands, the 2030 Agenda was conceived on September 2015 during the United Nations General Assembly. It is a document that encompasses objectives with a view to tackling global problems for the next 15 years (2016-2030), with these sustainable development objectives (SDGs) supported by three dimensions: social, environmental and economic. Among the 17 SDGs, two stand out, aiming at improvements in terms of quality education and gender equality, SDG4 and SDG5, respectively. In a report made in 2018, UNESCO — a United Nations agency specializing in education — places education in Science, Technology, Engineering and Mathematics (STEM) as one of the bases of the 2030 Agenda to achieve its goals, stressing that “ensuring that girls and women have equal access to STEM education and, ultimately, to STEM careers, is imperative for human rights, scientific and developmental perspectives” (UNESCO, 2018, p.15). Initiatives that take place at school, such as extracurricular activities, and joint projects with universities, have positive impacts on girls' interest in subjects and careers in the STEM field (Oliveira, Unbehaum, & Gava, 2019).

In view of this scenario, this study aims at reporting the activities developed by the Accelerating Girls project in Elementary School — an extension and research project from the University of Brasília developed in the scope of STEM education — reflecting on its reach and challenges in face of the promotion of female protagonism in areas of Exact Sciences and their technologies, especially with regard to their approach and execution with students from the public educational system of the Federal District, Brazil.

It should be noted that extension is one of the pillars of Brazilian federal institutions of higher education and comprises activities that aim to build paths to tackle social problems and issues, to popularize science, and to strengthen the interlocution with other knowledge, enhancing the interaction with teaching and research.

Given the context, the present research started from the need to identify more suitable strategies for the application of Active Learning Methodologies as an incentive and study motivation factor, and at the same time to stimulate the debate on the promotion of gender equality and empowerment of girls and women through STEM education.

The objective of this work is to present the aspects related to the development of STEM workshops in the ninth grade of a public elementary school and the learning gains of female elementary school students, monitors of this class, who participated in the development and execution of these workshops in the scope of a pilot proposal.

This is an action-research project in which proposals for the implementation of STEM workshops are carried out by the group of students and monitored during their realization. Reflections are made based on the results of the implementations and on interviews with the student monitors.

The work is organized as follows: the second section presents the bibliographic review that supports the measures adopted in the project; the third section exposes the context and model of the work conducted; the fourth section brings the partial results; and finally, the fifth section includes the concluding remarks of the developed research.

2 Active Learning and the Potential in Regard to Academic Protagonism

In the ideal future designed by the world nation, one of the main ideals is the respect for plurality and the appreciation of education in order to “ensure that all human beings can fulfill their potential in dignity and equality” (Agenda 2030, 2015, p. 1). It is common for each individual to have their particularities, so, in the field of education, it is natural that each student has preferences regarding the most effective study methods for themselves. Thus, seeking to respect students’ singularities, and make our education even more efficient, it is expected that as the ideal world is transformed into reality, new strategies and teaching-learning methods will be created and used.

Assuming that education is the main fuel for life improvements, it is important that the teaching-learning methods and strategies are able to promote the development of students' competencies and skills. Active learning strategies place the student in a more active role, contributing to the formation of responsible and critical citizens (Freire, 1997, p. 59). Placing the learner in a protagonist position means breaking away from the authoritarian model that reserves to the student the role of simply watching, listening and taking notes of pre-established contents (Felder & Brent, 2009). The report “The Future of Jobs” by the World Economic Forum (2020) points out some important and valued skills and competencies in the professional of the future. These skills and competences are: active learning, problem solving, critical thinking and analysis, creativity, originality and initiative; which are developed in activities such as debates, seminar presentations, experiments and workshop development.

These are knowledge sharing activities, and several tools can be used to make the process of intellectual gain more enjoyable. When the exchange is done horizontally, that is, by peers, it eliminates some obstacles that hinder learning. In this way, placing the learner as an active subject in the dissemination of knowledge encourages his peers to also feel part of this process.

In this dynamic, it is possible to work on communication strategies to promote the engagement of the parties involved, on research and study methods, on creativity in designing the presentation format of the content, and on skills with new active learning technologies. Thus, various aspects related to student empowerment, such as the responsibility to study and understand the subject before presenting the work, since she has the task of teaching the classmates, giving that student the right motivation to learn. Inverting the teacher-student role also affects the student's creativity when deciding which methods to use in order to make the presentation interesting, as he or she can create fun slides, search for videos, create quizzes, etc. In addition, it improves orality, argumentation and empathy, as Snider and Schnurer (2006) state in relation to debating activities.

There are several definitions and conceptions of active learning. Some definitions are presented by Mahlambi (2021):

According to Abu Bakar and Ismail (2020) and Jesionkowska et al. (2020), active learning is an action that directly involves learners in the process of learning. But Hartikainen et al. (2019:2-3) view active learning as “not just something that learners do independently but is somehow organised and monitored by an instructor, therefore, an instructional approach that guides learning”. The critical factor to active learning, especially in mathematics, is collaborative learner involvement which can assist the learner in improving their conceptions by using their peer explanations to solve problems (Webb et al., 2019). [...] Virtanen et al. (2017, p. 2) concur, citing that active learning is an “instructional method that engages learners and includes them as active participants in the learning process”. To enhance active learning, teachers need to guide learners to take responsibility for what they learn (Virtanen et al., 2017), particularly as active learning can improve learners’ attitude, understanding of the content (Mathias, 2014) and enhance the development of their mathematical skills. (Mahlambi, 2021, p. 473, 475).

The active learning conceptions comprise a constructivist vision with active student participation. In activities such as these, the student is not led to repeat the information provided by the teacher in a test, as is done in a traditional class, but he or she is invited to research the topic of the class by himself or herself, seeking concepts and information on that topic, develop them and explain them to the colleagues.

If colleagues do not understand, the student is challenged to explain the topic in a different way, making the student revisit the knowledge already acquired, reassess it and reconstruct a new argument that is more coherent or does not have logic errors. In case there are, the student responsible for explaining the task will be forced to question him or herself and re-evaluate the concepts. Thus, the goal is to create strategies to overcome the conceptual and epistemological difficulties manifested in the learning process.

Such activity, having so many layers, is one of the most powerful and efficient methods used in the teaching-learning process. Inverting the teacher–student role, and giving the student the opportunity to teach his or her classmates, enables the student to gain a greater understanding about the subject, since knowing how to explain a concept or topic in different ways shows that the student has truly studied and knows about the subject at hand (Srinath, 2014). It is important to support the students in the construction of a coherent knowledge and that they can actively participate in the recognition and construction of this knowledge “following the sequence: identification of the phenomenon, identification of the variables/elements involved, identification of interactions among them; search for regularities in the observed behaviors, conclusion on the concepts or law involved” (Bravo et al., 2022, p. 06, translated by the authors).

Thus, by placing students not as listeners, but as lecturers, debaters, monitors, the student almost completes the role of protagonist in the learning process. It is also understood that elaborating and conducting a workshop is not limited to explaining the class topic, but also to researching and elaborating didactic material, making the student-monitor role even more active in the studies, developing a sense of responsibility and motivation to learn and do a good job.

3 An Initiative that Aims at Gender Equity in STEM

The Accelerating Girls Project in Elementary School (MAF) is an extension project developed with female students from Elementary School Center 201 in Santa Maria, a public school located in the Federal District. In view of the low adherence of girls and women to STEM areas in higher education, which is related to the gender issue in education, the extension project acted in the planning, elaboration and execution of exact science

workshops with themes related to the school curriculum of the 9th grade of that elementary school using active learning methodologies in all activities. The project was conducted in 2021 and then due to the COVID-19 pandemic, took place remotely. Six female students were chosen by the school science teacher, who was a partner in the project, and the criteria used were based on their performance in science or their interest in participating in the project.

The direct work focused only on the female gender is based on studies that show that the group composed solely of women has more positive attitudes towards topics that are considered male-dominated (Cooper and Weaver, 2003)

The group that assists the students is made up of undergraduate students from the University of Brasília in the Statistics, Chemistry, Forestry Engineering, Mechanical Engineering and Electrical Engineering courses — they act as facilitators with the Elementary School students. The project also counts with the support of professors from the University of Brasília who work in engineering, education, psychology, sociology, design, and communication. They guide and supervise the activities developed. During the year, this team carried out workshops in which the main performers were the Elementary School (EF) students, who presented, based on their lesson plan, workshops to their colleagues in mixed classes, developing theoretical and practical aspects previously studied by the whole class.

The Accelerating Girls project in Elementary School was born as a segment of the Fast Girls project, which aims to encourage the entry of girls and women into STEM areas, being also developed with students from public schools, including High School ones. It is promoted due to the low permanence and interest of women in these areas.

According to Linda Gottfredson (1981), from the age of 6 to 8, children begin to form ideas about the influence of gender in relation to professions and this becomes evident when reaching adolescence, when abilities, values and interests based on childhood are used to make possible professional choices and roles to be taken. Several factors consolidate ideas on what would or would not be appropriate for a given gender, from stereotypes, self-esteem, expectations, gender roles to the absence of female role models (Munilla, 2018). This, when internalized, influences the vocational behavior of young people, limiting their achievements and aspirations (Betz & Hackett, 1981; Faria, Taveira, & Saavedra, 2008). Therefore, in order to promote gender equity and inclusion, it is necessary to act since basic education.

In this sense, the Accelerating Girls in Elementary School aims to foster interest and create a safe space for elementary school students, providing opportunities for the expression of creativity, logical reasoning and improving their interest in the areas of mathematics, science and technology. Thus, they are encouraged to face the likely difficulties related to the gender issue in their path, creating conditions so as not to interrupt this journey through educational practices which are sensitive to this problem.

3.1 Workshops Model and Methodology

Through active and collaborative learning models, development of practical activities and bringing scientific content closer to everyday life, workshops led by elementary school students were developed. The workshops followed the same structure, being divided into stages over five weeks: (1) Delimiting the themes of the workshop, and the beginning of the studies stage; (2) Designing the flipped classroom; (3) Slides preparation; (4) Experiment characterization. Preparation of quizzes and questionnaires; (5) Testing the workshop. After the stages had been performed, it was possible to present them to the target audience.

The workshops were planned according to the syllabus studied in the 9th year of Elementary School, covering topics such as matter and energy, covering areas of physics, biological sciences, mathematics, chemistry and others. Themes such as density, chemical reactions, waves and Newton's laws were the guiding principles in the four workshops held. Within them several aspects were discussed in a multidisciplinary way, contemplating both the theoretical and the practical parts of the deliberate areas. These various aspects can be observed in Table 1.

After having delimited the theme, a week was used for studies, carrying out research activities in books, websites, articles and searching for videos, images and various didactic resources to formulate ideas about the

chosen content. This step is essential for the delineation of the workshop's pillars, and it helps the elementary school monitors to remember and fix the content previously discussed in the classroom.

Perusall, a platform for inserting images, PDF and media files, hyperlinks and other resources, developed by educational researchers and behavioral and data scientists from Harvard University, was one of the resources connecting undergraduate monitors and elementary students because, in a versatile way, it was possible to highlight important parts of the texts, share new content, exchange comments and ask questions collectively, enabling an individual activity to be carried out in a collaborative way.

Based on the contents studied and the didactic resources that were grouped, a flipped classroom strategy was designed, preparing students for the contents that would be discussed later in the presentation. The flipped classroom has proven to be an important strategy for both preparing the elementary school monitors and delivering the workshop to the class. Wankat and Oreovicz (2015) defined the flipped classroom as a pedagogical approach that includes a three-step didactic sequence, pre-class, class, and post-class. In training the students to conduct the workshops, it is possible to distinguish the three stages: (i) previous studies on the subject; (ii) feedback and development of collaborative work; (iii) individual work.

Through videos, short texts, images and games, the students were expected to begin a brief study of the topic. The contents studied also contributed to the formulation of the presentation slides. These were developed from summaries written by the elementary students in their study phase, and included gifs, small texts, images and references. The last week execution of the proposed steps was related to the formulation and delimitation of experiments, quizzes and questionnaires.

Table 1. Workshops conducted and their specifications.

Workshop	Themes approached	Experiment(s)
Matter properties – Density	Concept of weight, mass, volume and density. Density calculation. Immiscible substances. Factors that can modify the density of a material. Relationship between temperature and density. Relationship between physical state of matter and its density.	Lava lamp
Chemical reactions	Meaning of chemical transformation. Signs of reactions occurring. How chemical reactions are written. Types of chemical transformations. Factors that prove the occurrence of a reaction.	Potassium permanganate solution, water oxygenated and manganese dioxide
Waves and wave phenomena	Definition of wave, amplitude, wavelength, period, speed and frequency of a wave. Wave classification. Direction of wave propagation and vibration. Examples of wave phenomena. Definition of sound waves and their properties.	Wave machine and experiment with sound waves
Newton's laws	Concept of kinematics and dynamics, and their differences. The history of Isaac Newton. Distinction of force and resultant force. Description of different types of force. Concept behind Newton's laws.	Experiment with coins (principle of inertia), experiment with eggs (law of inertia), experiment with displacement of a rubber (principle of dynamics) and experiment with balloons (principle of action and reaction)

The Elementary School students, after the steps outlined above, performed the presentation of the chosen theme. The class given was conducted as followed: theoretical presentation; resolution of doubts in relation to the theoretical part; quiz; experiment presentation; solving practical doubts.

The quizzes, which served as a way of evaluating the understanding of the workshops, were prepared by the elementary students. They included five to seven questions which were discussed in class after the theoretical presentation, in order to contemplate the main points that were exposed in the presentation.

Based on the fact that knowledge can only be developed in the individual's own action (Freire, 2001), the experiments were thought of as a way of correlating the contents taught with the knowledge and narratives that students observed in their daily lives, in order to make Physics and Chemistry more understandable and less abstract to students. These experiments were designed with accessible materials, made available to elementary school monitors by the guiding professors and purchased with resources offered by the Federal District Research Support Foundation (FAP-DF). All experiments were exposed to the class in order to highlight the materials needed for the elaboration and their step-by-step assembly. These could be replicated by the students in their homes.

Before the class presentation, the elementary students presented the complete workshop to the undergraduate monitors and coordinating professors, so that they could discuss aspects that could be improved and small adjustments could be made. That served as a rehearsal and the workshop improvement.

Questionnaires were prepared by the undergraduate monitors to assess the impact of the workshops on the classes where they were taught. They were sent after the end of the presentation. These involved questions including the flipped classroom, the experiment, and length of presentation, content presented, the quiz, the presenters' didactics, among others. The questionnaires contributed to changes throughout the workshops, making them adequate to the target audience. This moment was also important for their learning and autonomy in the process of designing and executing the workshops.

4 Results

The six female elementary school students who participated in the project during 2021 conducted four workshops as class monitors in a remote virtual environment for about 80 students, boys and girls in the ninth grade of a science class at Elementary School Center 201 in Santa Maria, on the outskirts of Brasília, Federal District. Figure 1 shows the cover of the material produced for the flipped classroom and screenshots of the presentation and the experiment performed by the elementary school monitors.



Figure 1. Workshop of Chemical Reactions: flipped classroom material; remote class presentation; and remote experiment.

To analyze the results obtained with the project, interviews were conducted with these six female students. The interview had 10 questions that addressed the thematic axes: (1) General aspects (issues related to STEM areas and active learning methodologies); (2) Adherence to the project; and (3) Encouraging protagonism.

When asked about the project's contribution to increasing their interest in STEM fields, all students answered affirmatively. One of the interviewees is considering studying aerospace engineering, while another reported an increased interest in robotics. It was also emphasized that, although they had not previously excelled in mathematics, participating in the project brought them closer to the STEM areas.

Regarding the small age difference between undergraduate and elementary school students, there was unanimity in highlighting the age range as a positive point, being interpreted as a contributing factor to the creation of a relaxed environment. When asked about the methods and strategies adopted, experiments and quizzes, these were positively evaluated, highlighting the playful and interactive nature of these proposals. The inverted classroom was also mentioned; they emphasized its important role in the study and individual preparation before the workshop with the undergraduate monitors.

One of the interviewees emphasized that the research activity helped thematic understanding in comparison with traditional learning methods. All of the interviewees evaluated the experiments as a facilitating strategy

for understanding the content. Such active methodology strategies, according to two of the interviewees, were responsible for their better performance in science assessments.

This effectiveness in performance on assessments changes how female students perceive themselves in the face of learning in STEM. The issue of vocation is called into question when girls realize that the problem is not an individual characteristic. The prejudices linked to gender begin to be addressed through the use of an active methodology that develops autonomy, interaction, and creativity.

Moving on to axis 2, about the questions referring to adherence to the project's gender proposal, when asked about the motivations needed to continue in the project, one of the answers was "I liked it a lot because there were only girls". One of the students commented that being with her classmates was a motivational factor to continue doing the workshops.

For those who left or thought of leaving the project early, they were asked to explain their motivations. One of the students explained that the pandemic and, possibly, remote learning, left her demotivated and, for this reason, she thought of leaving the project, but that after talking to one of the group members she decided to stay. This student participated in all four workshops and reiterated that, despite not being the central incentive, the CNPq scholarship she received encouraged her to keep going to the meetings.

All students confirmed their interest in participating in future project actions. In fact, four of them have already started to participate in the Fast Girls project after entering high school. One of the students said that the project during the pandemic was an encouraging factor for her, as it fostered interaction with other classmates, which was hindered by physical isolation during the pandemic.

In axis 3, which dealt with the students' protagonism in the project, all of them answered that they had autonomy to decide the themes of the workshops and discuss the strategies used, although one of the students commented that not all of them used this autonomy to give their opinion on the methods and strategies used in the workshops.

Finally, when asked about the benefits of having participated in the project and what they learned in the process that they would take back to high school, the answers ranged from improved teamwork dynamics to improved public speaking and presentation skills.

In this perspective, when acting as monitors, the elementary school students felt protagonists in the presentations and in carrying out the experiments, and realized greater resourcefulness, greater curiosity in the classroom and greater ability to understand and correlate content. Through the methods and strategies used and the production of materials based on the theories studied in class, the students were able to consolidate their knowledge and instigate classmates to think critically. Understanding that active learning requires questioning, problematization, and the sensorial and emotional experience of knowledge (Oliveira, 2006), which are not such characteristics explored in the standard learning process in which students absorb knowledge in a passive way (Leão, 1999). As we could see from the reports, the project correlated the contents to the students' reality, encouraging them to observe and question phenomena, allowed the appropriation of methodological tools, of experiences in the construction of scientific knowledge and its articulation with everyday life, as well as developing skills in organizing, planning, and executing the workshops.

5 Concluding Remarks

The selected students are a vulnerable group - taking into account monetary parameters, housing region and gender and race identification - in this sense, this is a valuable project in the socioeconomic sphere, being in line with what is advocated by Adams, Gupta and Cotumaccio (2014), who argue that science programs, outside the school, help in the trajectory of young people in the scientific world, especially girls from underrepresented groups in this area. Thus, it is generalized that, although it brings elements that are similar to successful initiatives regarding the encouragement of girls and women in STEM areas, because it is a project still in its infancy, the process of interest needs to be maintained and deepened so that it can introduce relevant changes that enable the promotion of the advancement of women that is necessary in the scientific and technological field, as well as in educational institutions.

The 2030 Agenda, together with UNESCO, has placed STEM education as one of the pillars for achieving this goal. In this sense, actions to encourage girls to engage in Science, Engineering, Technology and Mathematics developed while still at school age proved to be positive. In light of this, the project Accelerating Girls in Elementary School, with the use of Active Learning, developed its activities in order to encourage girls and women in the areas of STEM, encouraging the permanence of undergraduates in the areas and providing a more personal and active initiation of Elementary School students with Exact Sciences. In view of what has been exposed, the results obtained so far have shown to be promising, since even those students who had no initial interest in STEM remained motivated and participatory during the activities. Currently, the Accelerating Girls in Elementary School project aims to migrate to the face-to-face format without any loss in the quality of the workshops, evasion of monitors and losses of its central idea.

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Development and Validation of Scenarios for the assessment of Project Management People Competences

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Abstract

The development of project management competences, particularly people competences, is a challenging and complex process. Scenario-based learning is an interesting approach to developing these competences, involving real problems that allow you to face challenges based on your own experience. In this sense, scenarios act as the starting point for diving into a real-world problem and fostering the whole process of decision making and searching for solutions. The International Project Management Association (IPMA) has defined an Individual Competence Baseline (ICB 4.0) standard for the development of the project management area of knowledge. The standard shows, besides other competences, the following 10 people competences: personal communication; leadership; teamwork; self-reflection and self-management; personal integrity and reliability; relationships and engagement; resourcefulness; conflict and crisis; negotiation; and result orientation. Development and assessment of these competences are increasingly important for the people working on projects. In addition, there is an accreditation process for these professionals that is increasingly required by organizations. The process involves an assessment of technical qualifications to improve task performance. In this sense, this paper aims to describe the development and validation of ten project management scenarios that allow the assessment of people competences. The methodology of the study comprised six phases. In addition, two pilot applications were conducted with the proposal to assess competence of the scenarios developed. The findings reveal that the scenarios can be used as an alternative approach to the accreditation process of professionals who work in project management.

Keywords: Competences Development; Scenario-Based Learning; Project management; Engineering Education.

1. Introduction

The world is in permanent change. People, processes, and environments change and evolve at an ever-increasing rate in a world characterized by marked interconnections and externalities. Given this, it is quite naive to think that projects, and the individuals who participate in and manage them, will not need to adapt to and embrace change and uncertainty in order to successfully achieve their outlined goals (López-Alcarria, Olivares-Vicente, & Poza-Vilches, 2019). The people who manage projects (the project management community of practice) are increasingly requiring the development and assessment of these professionals (Alam, Gale, Brown, & Kidd, 2008).

As learning becomes more personalized and requires adjustment to changing conditions and requirements while meeting rigorous accreditation standards, new forms of assessment are needed (López-Alcarria, Olivares-Vicente, & Poza-Vilches, 2019). The use of scenarios, i.e., challenging situations inspired by project management practices, can be a valuable tool for both organizations and individuals to develop and assess their competencies. There is a growing interest in development and assessment of project management competence (Crawford, 2005).

In this regard, the research question of the study sought to understand, "In what ways do scenarios enable the assessment of project management competency?" The main purpose of this study is to describe the development and validation of Project Management scenarios for the assessment of competencies defined by the Individual Competence Baseline

2. Background

Recognized as a profession in the mid-20th century (PMI, 2017), project management continues to evolve, and as old methods undergo modifications, there is the creation of new tools and the emergence of research with new viewpoints in the profession (Wawak & Woźniak, 2020). This evolution represents the creation of several benchmarks that can be used as a basis for professional development and assessment. The Individual Competence Baseline (ICB4) is a reference source

for those seeking a method option in project management that is more focused on the human aspects of management, namely people competences (IPMA, 2015).

This benchmark was developed by IPMA (2015) and describes a coherent inventory of competence elements that an individual needs to have or develop to successfully master the work package, project, program or portfolio they have been assigned to manage (IPMA, 2015). Furthermore, it does not detail the competences by specific roles (e.g., project manager or planning specialist) but rather in terms of what is required in the domain of project, program, and portfolio management (Vukomanović et al., 2016).

The individual "competence" is the application of knowledge, skills and abilities in order to achieve the desired results (ICB4). The concept of competence is strongly associated with the ability to master complex situations. In the professional world, accreditation and training of professionals through proficiency testing is strongly demanded by organizations (Erol et al., 2016). The process involves the assessment of competences required for improvement in task performance. In the study of (Erol et al., 2016) a scenario-based Industry 4.0 was developed to assess how common problem engineering competences can improve performance.

Several research papers have focused on the development scenarios to assess competences (Ilahi et al., 2014). However, competence assessment is not very well researched in the context of project management, and there is a gap in competence assess models (Ilahi et al., 2014). In this sense, although changes have occurred as a result of the emphasis on competence-based learning, both in the academic and professional worlds, assessment processes are often based on traditional models (Ilahi et al., 2014). In fact, in the practical world, professionals or academics are more often faced with situations where they have to apply their acquired competences, but they are still examined by traditional assessment models (Ilahi et al., 2014).

In the fields of Medicine and Nursing, one of the approaches used to assess competences is centred on the principles of competence assessment through simulated scenarios (Hagler & Wilson, 2013; Waxman, 2010). In general, this approach of scenario can be used both for assessment and for learning purposes, where the individual passes through a simulated situation that is aligned with the behaviour they would adopt in a similar situation in real life (Banerjee, 2019).

As defined by Rosson & Carroll (2009, p. 149): "...like any story, a scenario consists of a context, or state of affairs; one or more actors with personal motivations; knowledge; capabilities; and various tools and objects that the actors encounter and manipulate. The narrative describes a sequence of actions and events that lead to an outcome. These actions and events are related in a context of use that includes the goals, plans, and reactions of the people who are part of the episode."

The use of scenarios has potential application in many contexts, problems, issues, and when used in the classroom provides a useful means for students to approach the reality of their profession (Errington, 2011) by applying their knowledge and competences to solve issues in a safe environment (Erol et al., 2016). In this sense, students, as potential professionals, are confronted with a description of the scenario, where they should assume roles or certain specific perspectives to explore it in order to enrich and complement the application of their competence in a professional context. Notably, scenarios do not replace work immersion, but through them, there is the construction and deconstruction of authentic experiences (Errington, 2011).

A scenario-based assessment involves asking participants to answer questions or challenges related to a short case, where the assessment is supported by a scenario, several questions or challenges related to it, and a system for assigning scores (Daniel & Mazzurco, 2019). The application of case studies can be seen as an appropriate methodology for competences development, and in particular in preparing for the professional world of project management, because it allows the participant to apply the knowledge learned, enabling reflections of what went well, what went wrong, and what would be most recommended for improvement in the future (Kerzner, 2006).

According to Hagler & Wilson (2013), there is little research that develops guidelines for writing and using scenarios, also little has been found in the project management literature assessment models through scenarios. In general, scenarios should be able to require the participant to perform the competences being assessed and match the level of complexity of the actual task (Hagler & Wilson, 2013). However, before the competence can be assessed through the scenarios it is necessary to plan and develop processes, tools, and resources (Hagler & Wilson, 2013).

(O'Brien, Hagler, & Thompson, 2015) highlight a set of best practices that should be considered when developing scenarios for competence assessments, the first consists of a good theoretical foundation to identify the objectives or competences that are significant for the assessment, the second best practice refers to the selection of parameters for the scenarios, these parameters should be evidence-based, i.e., be grounded in practical guidelines that allow the simulation of real scenarios. The third best practice has to do with the link between the assessment elements, namely: the competences that are to be assessed, the instrument to be used in measuring the competence, and the scenario itself. Based on these best practices, the authors proposed an eight-step validation process for scenario design in simulation-based competence assessment.

First define the purpose of the proposed assessment (Step 1), then select a measurement instrument useful for the intended objectives (Step 2). In designing the scenario, a literature review is required (Step 3), then the scenario must be written and mapped (Step 4), the validation team must be selected (Step 5), and the method of conducting the validation process must be developed (Step 6). Finally, test the scenario (Step 7) and review and assess the feedback (Step 8) (O'Brien et al., 2015).

Given this, sought in this study, develop scenarios with real situations of project management, which were able to assess the people competences of professionals working in the area.

3. Methodology

The methodology of this study comprised six (6) steps for the process of developing, validating and assessing scenarios to assess on Project Management people competences. The steps of the study were adapted from the study by O'Brien et al., (2015). Table 1 shows the steps adapted for the study.

Table 2. Steps of the study

Steps (O'Brien et al., 2015)	Adapted steps (O'Brien et al., 2015)
1. Define the Purpose	1. Define the Purpose
2. Select the Tools	2. Review and selection of studies
3. Review the Evidence	3. Development of scenarios
4. Write and Map the Scenario	4. Review Linguistic of scenarios
5. Select a Validation Team	5. Validation of scenarios
6. Seek Consensus	
7. Pilot the Scenario	6. Pilot study
8. Assess and revise	

Step I. Define the Purpose: the purpose of developing scenarios is to integrate these scenarios into an assessment model of engineering project management competences (study under development). Assessment through scenarios is characterized as an approach that makes it possible to represent real situations or situations inspired in the professional reality of project management, thus, the purpose in developing scenarios is to assess project management competences.

Step II. Review and selection of studies: understanding and selection of studies was defined as the second phase, which aimed to search for general studies on scenarios, as it allowed identifying information, facts and evidence. This activity was developed searching the Scopus database. The end result of this phase was a general understanding of scenario-based learning in a variety of contexts. The authors (Wawak & Woźniak, 2020; Ilahi et al., 2014; Hagler & Wilson, 2013; Erol et al., 2016; Banerjee, 2019; Errington, 2011; O'Brien et al., 2015) were references in this phase for a general understanding about scenarios. It is important to mention that other studies contributed with less significance. However, we felt the need to deepen the analysis considering the engineering area. Following the procedures developed in the Scopus database, selecting only journals linked to the engineering area, resulting in 44 studies. Additionally, some works from the Project Management area of knowledge were also analysed: Kerzner (2006); PMI. (2017) A guide to the project management body of knowledge (PMBOK); IPMA/Individual Competence Baseline for Project Management (ICB4) and Miguel, A. (2019).

The Individual Competence Baseline for Project Management (ICB4) was the work selected as the fundamental work for this article. Defined as an International standard and developed by more than 150 experts on the subject, it presents a complete inventory of key individual competences for people working on projects. In this sense, it is characterized as a validated and complete instrument when seeking to develop and assess competences. It presents three domains of individual project management competences: perspective, practice and people competences.

For reasons related to time and capacity limitations it was decided to select the people competences domains, including the 10 (ten) people competences and the assessment criteria (indicators and performance measures), which will be used to describe and assess the scenarios.

Step III. Scenario development: for the development of the scenarios the 10 (ten) people competences described in the (ICB4) defined by the International Project Management Association (IPMA) were used in the study. In this sense, each scenario seeks to assess a specific Project Management competence, as an example: scenario 1 is based on the personal communication competence, scenario 2 is based on leadership and so on. Thus, each scenario assesses a base competence. Table 2 shows the scenarios that were developed in the study.

Table 3. Scenarios developed

Scenarios	Base Competence
1	Self-reflection and self-management
2	Personal integrity and reliability
3	Personal communication
4	Relationships and engagement
5	Leadership
6	Teamwork
7	Conflict and crisis
8	Resourcefulness
9	Negotiation
10	Result orientation

Step IV. Review with a Professional Social Science and Project Management Professional: the third phase of scenario development, comprised an in-depth review of the scenarios by two scholars, working in the fields of Educational Sciences and Project Management. The process aimed at two key inputs: (i) Linguistic review, and (ii) Review the content. Suggestions for improvement were analysed and the main improvements suggested were implemented.

Step V. Validation with professionals: whose objective focused on the collection of the first perceptions about the scenarios, problems that were exposed and actions for improvements with key informants. The key informants were professionals who work in the area of project management. Thus, for the selection of the professionals, two basic criteria was considered: professional experience linked to engineering projects and/or complementary training linked to the area of project management. With this in mind, a questionnaire survey was developed and sent via email, with open and closed questions; the questionnaire was created with 20 closed questions and 10 open questions. The closed-ended questions were answered using an agreement Likert-type scale, ranging from 1 to 5, represented qualitatively by the following perceptions: "1. totally disagree"; "2. disagree"; "3. neither agree nor disagree"; "4. agree"; "5. totally agree". An invitation was sent, via e-mail, to 10 professionals, and we obtained the acceptance of all professionals. However, after sending the survey by questionnaire, a deadline of 30 days was offered, and at the end of the deadline, we obtained a total of 7 respondents. Table 3 presents a summary of the characterization of the profile of the professionals who were surveyed in this phase.

Table 4. Characterization of professionals

#	Basic Training	Training Additional	Experience in the area
1	Mechanical Engineering	Specialization in Project Management	5 years
2	Mechanical Engineering	Specialization in Project Management	1 years
3	Plastics Engineering	MBA in Project Management MBA in Careers, Leadership and Coaching	12 years
4	Business Administration	Professional Master's in Administration	10 years
5	Agronomic Engineering	Master's in Project Management	2 years
6	Production Engineering		6 years
7	Mechanical Engineering	Specialization in Project Management	10 years

The qualitative analyses of the survey results focus on the open-ended questions in the questionnaires. For each scenario presented, a question regarding suggested improvements was asked to the respondents. The quantitative analysis of the surveys went through statistical treatment which consisted of classification, calculation and analysis procedures. For this, the program SPSS (Statistical Package for the Social Sciences) version 26 was used. The analysis used was the calculation of Cronbach's Alpha coefficient.

Cronbach's Alpha coefficient is a technique used to assess the reliability and internal consistency of instruments. The objective in using the coefficient is to ensure the accuracy/reliability of what has been developed. In this sense, the coefficient measures the degree of reliability of the information obtained (constancy of the results and homogeneity of the items).

Step VI. Pilot study: with the scenarios statistically analysed from the standpoint of professionals in the field, the fifth phase of this study sought to apply the scenarios. To this effect, the scenarios were applied, and an assessment of project management competences was simulated by using scenarios. With this in mind, participants were sought who could contribute to the analysis of the scenarios. To this end, two criteria were defined: volunteers and students enrolled in the same academic year of the Integrated Master's Degree in Industrial Engineering and Management (MIEGI) of the University of Minho, Portugal. The objective in assessing these scenarios was to know the perceptions of the participants about the understanding, time estimation (reading and response), advantages and limitations identified in the scenarios and in the assessment of competences by scenarios.

In this sense, the pilot studies were organized in two groups of participants, with pilot study 1 being conducted online and pilot study 2 in person. It is important to mention that the choice of dividing the application of the scenarios into two groups of participants was an option of the authors due to the issue of the physical structure that could hold all the participants at the current moment (world pandemic). In pilot study 1, three participants were involved, and each participant answered one scenario: personal communication, leadership, and teamwork, and it was carried out in the month of December/2021. The second pilot contained three participants involved and the data collection process took place, face-to-face, in a room located at the University of Minho, exclusively for the process. For this group, seven scenarios were assessed: introspection and personal management, personal integrity, relationships and commitments, conflict and crisis, ingenuity, negotiation, and finally, results orientation. The pilot study was conducted in the month of March/2022. Figure 1 shows the main activities conducting the study I and II.

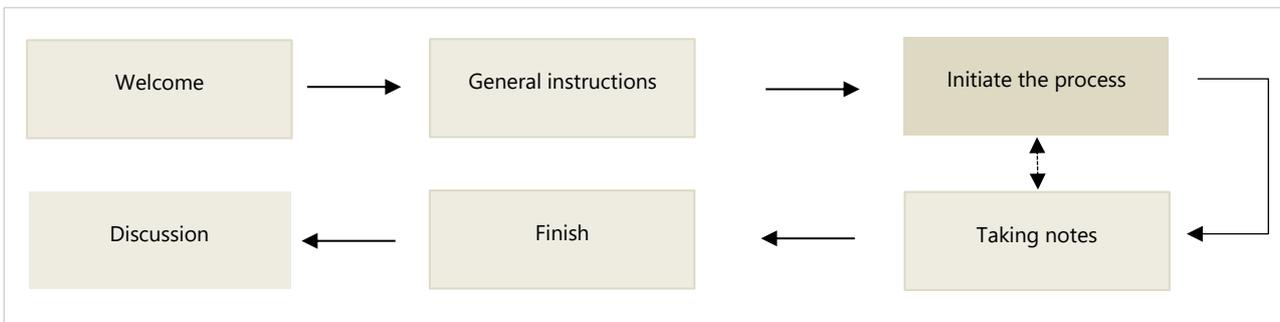


Figure 1. Activities Pilot Studies

In addition to the participants, an evaluator and a mediator were present in the studies. The assessor a professor with a doctorate and research focus on teaching and project management, with teaching experience in competence development and assessment, and the mediator was a professor with a focus on assessment studies of project management competences.

4. Development and Validation of scenarios

Developing scenarios for assessing Project Management people competences enables an assessment that mobilizes different resources, including knowledge, competences and experience in addressing a problem related to professional practice. Creating real or reality-inspired situations makes the assessment process "more flexible" and real in that one must mobilize different kinds of knowledge, not just memorization to deal with that problem situation. As an example, a question developed by the evaluator in some of the scenarios and which makes it possible to mobilize different resources: *"Have you been through a situation similar to this one (exposed in the scenario), either as a leader or as a team member? If yes, what actions did you take that you think could be useful for this scenario?"* Each scenario developed reflects a practical project management situation and makes it possible to assess competences.

4.1 Analysis of Scenarios – a quantitative perspective

The professionals' contributions allowed to integrate a more realistic perspective to the scenarios. The result obtained indicated a value of the Coefficient Cronbach's Alpha, considering all dimensions, of 0.89, a value considered to be of almost perfect reliability, according to parameters used by (Landis & Koch, 1977). According to (Landis & Koch, 1977) the classification of the coefficient reliability follows the following limits: 0.81 to 1.0 almost perfect; 0.61 to 0.80 substantial; 0.41 to 0.60 moderate; 0.21 to 0.40 reasonable; 0 to 0.20 small.

For the data analysis of the questionnaire applied to the project management practice professionals for each scenario two closed questions and one open question were developed. The closed-ended questions were answered using an agreement Likert-type scale, ranging from 1 to 5, represented qualitatively by the following perceptions: "1. totally disagree"; "2. disagree"; "3. neither agree nor disagree"; "4. agree"; "5. totally agree".

Regarding the following question: *"Does the scenario represent a situation of Project Management professional practice?"*. The data presented in Table 4 indicate that in the self-reflection and self-management and personal integrity and reliability scenarios 2 out of 7 of the respondents indicate that they do not agree with the representation of professional practice in the scenarios. In addition, the leadership and teamwork scenarios reveal some indecision on the part of respondents. In the other scenarios the results indicate agreement in the representation of the practical situation of project management.

Table 4. Answers from 7 professionals regarding the representation of professional practice situations

Scenarios	Base Competence	Totally disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Totally agree (5)
1	Self-reflection and self-management		2	1	2	2
2	Personal integrity and reliability		1		4	2
3	Personal communication			1	4	2
4	Relationships and engagement		2		3	2
5	Leadership			2	3	2
6	Teamwork		1	2	2	2
7	Conflict and crisis				3	4
8	Resourcefulness				3	4
9	Negotiation			1	2	4
10	Result orientation				4	3

Regarding the analysis of the second question *"Does the scenario provide the opportunity to demonstrate competence?"*. In the personal communication scenario one expert indicated disagreement with the statement. In the scenarios, relationships and engagement, leadership, conflict and crisis and negotiation there was indecision by one expert. Finally, in the remaining scenarios, there was agreement on the scenario's opportunity to demonstrate the core competence. The results are shown in Table 5.

Table 5. Answers from 7 professionals regarding the opportunity to demonstrate the core competence

Scenarios	Base Competence	Totally disagree (1)	Disagree (2)	Neither agree nor disagree (3)	Agree (4)	Totally agree (5)
1	Self-reflection and self-management			2	4	1
2	Personal integrity and reliability				4	3
3	Personal communication		1		5	1
4	Relationships and engagement			1	3	3
5	Leadership			1	3	3
6	Teamwork				3	4
7	Conflict and crisis			1	3	3
8	Resourcefulness				4	3
9	Negotiation			1	2	4
10	Result orientation				4	3

4.1 Analysis of Scenarios – a qualitative perspective

The qualitative analysis of this study occurred in two moments: i) analysis of the improvements in the scenarios from the professionals' point of view, regarding the open question of the questionnaire; ii) analysis of the narratives of the pilot studies. The main results will be presented regarding the proposed improvements for the scenarios.

Regarding the Self-reflection and self-management scenario, professional 3, indicated:

"Since it is an aid and/or recommendation to the colleague, it seems to me that what we will be able to extract from the interviewee, will be a transfer of best practices and experiences".

Regarding the communication scenario, two main propositions were evidenced:

"...in previous moments the Project Manager had already mentioned that in situations like this it would be necessary to attend and consider procedures such as..." (professional 3).

"Emphasize the importance of performing the activities according to the procedures, making it clear that, any problem should be communicated to the project manager" (professional 7).

For the leadership scenario:

"It is necessary to include in the scenario the step that involves eventual attitudes thought and/or designed by the manager, to be taken or put into practice" (professional 3).

"I think it is important to emphasize in the scenario that the "project manager" is hierarchically superior to the "construction coordinator". The nomenclature of the position, if misinterpreted, can distort the argumentation" (professional 4).

Regarding the teamwork scenario:

"I would modify in the sense that the team leader is centralizing all the information and decision making, changing the context that he would be doing everything alone, but centralizing all the decisions with him" (professional 1).

As for the conflict and crisis scenario the inclusion of discordant points was suggested:

"We could include the possibility of the Leader obtaining from the team, alternatives in points where there is no consensus" (professional 3).

For the negotiation scenario obtained the proposition:

"I would include in the text not only that the "client may not be happy with the deviation" but also, more explicitly, that the client believed in the schedule and is already starting to have financial losses with this delay. This places on the interviewee a need to search for "arguments" more connected to the reality and practice of the business and how he would face the situation" (professional 3).

With the analysis of the results of the ten scenarios developed from the professionals' point of view the main suggestions were analyzed and included for the pilot studies. That said, the second part of this study, focused on the qualitative analysis of the pilot studies from the students' point of view. The objective in assessing these scenarios was to know the perceptions of the participants about the understanding, time estimation (reading and response), advantages and limitations identified in the scenarios and in the assessment of competences by scenarios.

Regarding the understanding/comprehension of the ten scenarios developed, all participants affirmed that there were no doubts. Furthermore, the data indicate that 100% affirmed that the time for reading the scenario, estimated at 2 minutes, was adequate. With regard to the time for answering the scenario estimated at 8 minutes, all respondents indicated that perhaps the time was too long and justified their response.

"8 minutes is a very good time to discuss, but maybe 5 minutes is enough" (student 1).

"In my opinion, a response time to the scenarios of 8 minutes is high since it is only one person talking, discussing about the best decision to make in a specific situation" (student 2).

"Even with the additional comments and discussion with fellow observers, I think 8 minutes was too long for the scenarios" (student 3).

When asked about the main positive aspects of the experience of an assessment using scenarios, the results indicate that the respondents perceive positive points of an assessment by scenarios, allowing them to explain their arguments in an open and creative way in specific contexts of the area. Furthermore, they affirmed that the assessment that includes scenarios becomes diversified and representative and can be an important instrument for managers to present their competences. Below are some of the participants' descriptive answers.

"It is an experience that allows candidates to explain their reasoning openly and allows for a very diverse and representative assessment" (student 1).

"With the use of scenarios, it is possible for an evaluator to see, in a practical context, what a candidate's action would be in various situations, which is an advantage compared to the assessment only by competences mentioned in a curriculum, for example, and not effectively verified" (student 3).

When questioned with the difficulties felt in this assessment experience through the use of scenarios, two students directed to the lack of practical experience in the area, leading to difficulties in the argumentation in the answer.

"Some lack of knowledge on how to deal with the content of some scenario. From the functional point of view of the method I had no difficulties" (student 1).

"For me, the biggest difficulty in this experience was to put myself in the position of the project managers of the scenarios in which I was allocated and make the best decision. Another difficulty was in the argumentation of my decisions" (student 2).

"The scarce experience in the labor market limited the answers to the scenarios to the use of teamwork experience only in the academic context" (student 3).

Finally, participants described in their own words their participation in the study. The responses indicate an enriching and valuable experience. Unanimously, they enjoyed and felt comfortable in assessment of this type. Below are some of the responses.

"I consider this a very enriching experience in that it allows candidates to try to develop their soft competences, such as thinking about various possible situations. From the assessment point of view, I think this is a very complete method, which allows us to make a very representative assessment of the candidates and has a lot of potential to be applied in several areas. I didn't know about it, and I really enjoyed the experience" (student 1).

"I liked participating in this experience, I think it was well thought out and structured. The different scenarios were interesting and their contents allowed for engaging discussions" (student 2).

"I found it a very interesting experience, which I had never been exposed to before and it seems like an excellent way to also prepare even students for the job market/job interviews" (student 3).

5. Discussion

In this study, it can be verified that the assessment of competences using scenarios (problem situations inspired by real situations of professional practice) was evidenced by the participants as an excellent possibility for the assessment of competences. The suggestions for improvement from the professionals' point of view sought to align the scenarios developed with the real situations of the professional practice of project management and also the perception of the demonstration of the competence

Several authors identified benefits of scenarios in assessment processes (Klassen et al., 2021; Lovell & Khatri, 2021; Naidu, 2010; Seddon, McDonald & Schmidt, 2012): increased motivation and interest, engaging process and learning and more effective assessment (Ribchester & Healey, 2019) emphasize the realistic factor, encourage reflection and promote individual responsibility.

In this study, some of the benefits were evidenced. Benefits such as a dynamic and interactive, diversified and representative assessment, with the possibility of explaining the reasoning in an open manner and also aligned with professional practices of project management made the assessment approach by scenarios a possibility to assess people competences, since the assessed could mobilize different resources in solving a problem situation that is presented by the scenario.

Still, the assessment of competences by scenarios can be useful for accreditation, recruitment and team building processes, as it allows mobilizing different types of competences in simulated situations close to professional practice, diversifying the competence assessment processes and allowing the assessed a more flexible and real situation.

6. Conclusion

The objective of the study was to develop project management scenarios for assessing people competences. The importance of assessing these competences in the Project Management area is undeniable, and in this sense, assessment through scenarios becomes an excellent way to prepare professionals effectively for their practice.

The main results of the study indicate that the ten scenarios developed and assessed present benefits and provide the participant with the mobilization of resources, competences and experience to solve the problem to which he/she was exposed. In addition, the statistical analysis show high level of agreement from the point of view of professionals regarding the representation of project management practices, but show allow the need for review of some of the scenarios before the application in assessment processes.

As future work, scenarios will be improved, and instruments to support the assessment process will also be developed, i.e. rubrics for competence assessment will be developed for all people competences scenarios. With the scenarios and rubrics for competence assessment, a model for assessing Project Management people competences will be developed tested.

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IEM@ProjectNetworking revisited: freshmen students closer to professional practice

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Abstract

This paper describes a challenge given to freshman students of the Integrated Master degree of Industrial Engineering and Management (IEM) – University of Minho, Portugal. It was developed in the context of the Integrated Project of Industrial Engineering and Management 1 (IPIEM1). First-year students were challenged to interview an Industrial Engineer, or someone with this function, in a company. That was the second time the challenge was proposed to students of this program, after the first time in 2013. The challenge, called “IEM@ProjectNetworking”, has as main idea to allow students, on their own, to establish network with an IEM active professional and to get a full picture of what could be their future career. Students worked in pairs and had a semi-structured interview guide to help them to perform the interview. All interviews were synthesized in a written report and in a summary presented orally. Thirty-three interviews were conducted and assessed by a group of teachers and researchers. Teachers believe that by presenting this challenge, students will be more focused and aware of the contents given in the courses of the following semesters. At the same time, teachers obtain a perspective of what IEM professionals are doing and update their knowledge about industry needs. In fact, many findings were obtained with this challenge, namely: 1) a company database and the connection to IEM professionals for their future contact; 2) the stimulus of students’ capacity of initiative; 3) the students learned how to prepare and conduct an interview, to communicate, to extract the most important from an interview; and; 4) the students acquire knowledge where they can work and the variety of functions which they may be engaged. The assessment was based on how the task was organised and accomplished (written report and oral presentation in pitch format). Based on the analysis of results obtained from an online survey applied to students and their feedback during the oral presentation, it is possible to state that the challenge has been mastered perfectly, with a “mission accomplished” feeling.

Keywords: Industrial Engineering and Management Education; Active Learning; Networking, Professional profile, Transversal competencies.

1 Introduction

Normally, first year students (freshman) of Higher Education Institutions do not know much about their future professional career. This is generally the case in Engineering Education programs but it became more visible in Industrial Engineering and Management (IEM) programs, as this engineering has been evolved from different sources (Pimentel et al., 2022). Also, in the future they could perform so many different functions by taking different roles in the companies, from production systems designers to health and safety experts.

The Institute of Industrial and Systems Engineers (IISE) defined Industrial Engineering as: “... concerned with the design, improvement and installation of integrated systems of people, materials, information, equipment and energy. It draws upon specialized knowledge and skill in the mathematical, physical, and social sciences together with the principles and methods of engineering analysis and design, to specify, predict, and evaluate the results to be obtained from such systems.” (IISE, 2022).

The IISE is composed of 14 knowledge areas: 1) Work design and measurement; 2) Operations Research & Analysis; 3) Engineering Economic Analysis; 4) Facilities Engineering & Energy Management; 5) Quality & Reliability Engineering; 6) Ergonomics & Human factors; 7) Operations Engineering & Management; 8) Supply Chain Management; 9) Engineering Management; 10) Safety; 11) Information Engineering; 12) Design & Manufacturing Engineering; 13) Product Design & Development and, finally; 14) System Design & Engineering. It is expected that IEM students acquire knowledge and act on these areas in their later future professional in

any type of company or organization, producing goods, services, or both. Furthermore, they must develop competencies that go beyond the knowledge, including the skills and attitudes. This means that skills such as communication, problem solving, critical thinking, teamwork, leadership, capacity of initiative, among others, must be part of their learning.

With so many areas, it is not a surprise that IEM students do not know what will be their role in the companies. Moreover, they need to understand the meaning of learning in such knowledge areas that are included in their curricular plans. Attending to this, a challenge was launched to the IEM first-year, first-semester students called IEM@ProjectNetworking. This activity was developed in the context of Project-Based Learning (PBL) as a milestone to accomplish in the Integrated Project of Industrial Engineering and Management course. The students organized themselves in pairs and had to conduct one interview with an Industrial Engineer or someone that had this role in a company located in the region. The objective of this paper is to present how the challenge was launched, planned and executed and to analyse and evaluate the results obtained by students.

The paper is structured in five sections. After this introduction, the study context and previous work are presented in section two. Section three presents the research methodology. Section four presents the results obtained by students and the main findings of the authors about this challenge. Main conclusions are presented in section five.

2 Study context and previous work

The PBL learning methodology is being used by Industrial Engineering and Management (IEM) program of the School of Engineering of the University of Minho (UMinho) since 2004 (Alves et al., 2020; Lima et al., 2007). From a formal structure without a project course (Alves et al., 2014) to the current one, a long path of 19 editions was carried out (Alves et al., 2021). Along this path, a lot of research and continuous improvement has been done (Alves et al., 2017; Alves & Leão, 2015). This included the challenge of IEM@ProjectNetworking that was developed, for the first time, in the context of the course of Introduction (or Topics) of Industrial Engineering and Management (Alves et al., 2013). The setting for the challenge of this academic year was different and it is explained next.

Imposed by government, this academic year of 2021_22 implied one more change: from a Master Integrated of five years (300 ECTS) it becomes a Bachelor of three years (180 ECTS). The setting up of this paper is based on the 2021-2022 curricular structure conducted at the UMinho, as represented in Figure 1. From Figure 2 it is possible to see that the six courses that are integrated in the curricular plan are from different schools and departments, having a Science, Technology, Engineering and Mathematics (STEM) structure.

Regime	Curricular Unit
Year 1	
S1	Calculus for Engineering
S1	Computer Programming I
S1	Integrated Project in Industrial Engineering and Management I
S1	Introduction to Economics Engineering
S1	Introduction to Industrial Engineering and Management
S1	Linear Algebra for Engineering

Figure 1. Curricular plan of IEM first-year, first semester, IEM11

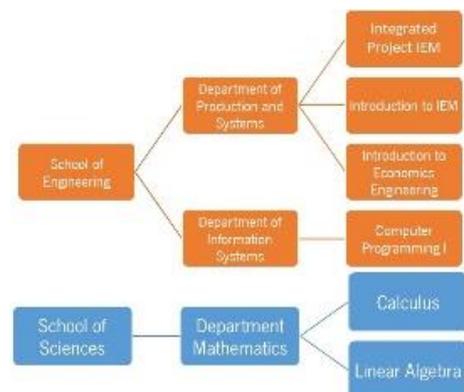


Figure 2. Schools and departments involved in the IEM11

The 67 students of this cohort were organized in eight teams of seven-nine members that need to develop a project in the context of the course Integrated Project in Industrial Engineering and Management I (IPIEM1), applying the contents learned in the five different courses. Each course has their own assessment methodology that includes a project component. Nevertheless, the contents of each course included in the IPIEM1 is assessed

in the presentations, reports, blog, prototypes, that the teams delivered to be assessed. Figure 3 shows the milestones of the IPIEM1 and the weight of each deliverable in the assessment methodology. Individual grade of each student is the result of (a) team grade influenced by a correction factor that result from the peer assessment (Fernandes et al., 2009; Fernandes et al., 2020; Uebe-Mansur & Alves, 2018) (90%) and (b) the grade obtained to the IEM@ProjectNetworking.

Ms	Week	Deliverable	Weight (%)
1	Week 2	1st presentation	not assessed
2	Week 6	2nd presentation	7,5 (team)
3	Week 8	IEM@ProjectNetworking presentation	10 (individual)
4	Week 11	Preliminary report	25 (team)
5	Week 13	Final report + Prototypes + blog	30 + 20 + 5 (team)
6	Week 14	Final presentation & discussion	12,5 (team)

Figure 3. Milestones (Ms) and weight of each in the assessment

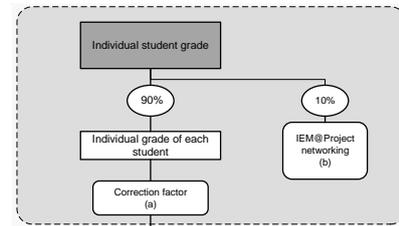


Figure 4. Individual grade of each student

3 Research methodology

The research methodology used by the paper authors to analyse the IEM@ProjectNetworking developed by the students was a content analysis of the interview transcriptions that were described in a report and personal reflections held by students in the oral presentation. Also, two questions related with this challenge were included in the survey that had been used to evaluate the PBL process every year (Alves et al., 2020). The non-parametric test Mann-Whitney (U) for comparison between the ranks of two independent samples, after verification of normality by Shapiro-Wilk test. The statistical software SPSS 28.0 was used for the analysis, and the effect is considered statistically significant for a $p\text{-value} < \alpha$ (the significance level). The process of data collection involved 67 students, who mostly worked in pairs, with 33 interviews conducted in a total of 37 companies.

The research involved the four authors of this paper, two of them teachers: one in the course of Introduction (or Topics) of IEM and simultaneously the coordinator of IPIEM1 and the other is coordinator of the course of Computer Programming 1. The other two research members had different roles in the project: one is tutor of a student's team and the other is an educational researcher. The four assessed different criteria defined for this challenge. The criteria considered were: 1) accomplishment of the interview guide topics; 2) reflection about the interview process; 3) auto-reflection; 4) accomplishment of the topic related to the information system; 5) assessment of the interview contents and finally, 6) accomplishment of the delivery conditions (deadline, all documents and audio/video delivered).

As defined by the criteria, the data considered in the findings focused on the reflections written by students concerning the overall process (before, during and after) of the experience of interviewing an IEM professional in their field, more than just simply describing the content of the interview. The students also discussed the main benefits and difficulties related to this experience. The assessment was based on how the task was organised and accomplished (written report and oral presentation in pitch format).

4 IEM@ProjectNetworking

This section describes the purpose of the IEM@ProjectNetworking challenge, the interview guide used and the results obtained.

4.1 Purpose

In the first stage, the challenge was presented to students with the main goal of explaining the purpose and what was expected from them. The main purpose was presented as:

- To develop proactive attitude;
- To develop awareness of the importance of entrepreneurial attitude.

Nevertheless, objectives also included:

- To bring students closer to their future professional practice;
- To develop a proactive and entrepreneurial attitude, student's initiative and communication competences;
- To develop a proactive attitude towards their own future as industrial engineering professionals;
- To develop awareness among the students on the importance of perseverance and proactive attitude;
- To create a network of contacts of IEM professionals and potential employers;
- To get familiar with IEM professionals point of view as well as with their role in the organizations.

4.2 Interview guide

To collect information from the IEM professionals, the interview was considered an appropriate method to give students a structured tool when approaching the companies. A semi-structured interview guide, adapted from an existing guide, included eight main sections:

- 1) Introduction, to inform about the interview objectives, highlight the importance of the collaboration, assure the confidentiality and ask for authorization to record the interview;
- 2) Interviewee profile, in order to know the academic and professional background;
- 3) Transition to workplace, in order to know the difficulties and expectations related to this issue;
- 4) Activities/functions held in the company, in order to understand what an industrial engineer is able to do;
- 5) Importance and recognition of the IEM profession, in order to analyse the employability issues, the advantages and disadvantages related to being an industrial engineer;
- 6) Personal satisfaction and professional achievement, in order to understand how professionals manage their time between personal and professional life;
- 7) Production Information system, to know more about the software used by the company, information needs, production management tasks supported by the information system, responsibilities of this task and access privileges;
- 8) Final observations, to give opportunity to the interviewees to add more information and acknowledge the availability.

The semi-structured interview guide document includes also some recommendations and tips of how to conduct an interview and some relevant literature regarding this topic. With this documentation in their hands, students had to select a company and manage to schedule an interview with an IEM professional with a relevant position in terms of production management. At the scheduled moment, students, in pairs, had to perform the interview, eventually make a small tour in the company and collect as much relevant data/information as possible. Finally, each student pair had to write a report presenting the interview results as well as a personal reflection on their experience of carrying out the interview and present the results in a five-minute oral presentation.

4.3 Results

As expected, this was not an easy task, not for the students neither for the authors that had to collect and assess 33 interviews, including the reports and audio/videos presented. For the authors, this task involved a high consuming-time, not considered in the workload defined for the project, that, normally, implies a high workload (Alves et al., 2009; Alves et al., 2019). Additionally, the content analysis of the report could conduct to different interpretations and unfair assessment between students grade but this is inherent to all other assessments (Fernandes et al., 2012, 2021). Nevertheless, it is of general opinion that should be repeated every year, since it was assumed as teachers team task (Alves et al., 2021; van Hattum-Janssen et al., 2022). The students organized themselves to conduct the interviews, some online due to pandemic restrictions, others had the opportunity to visit the company and conduct the interview face-to-face. Difficulties reported by the students were, mainly, related with the time management, as they also complain about the time they dedicated to the IPIEM1. The presentation of the Project Networking took place in an online format by zoom (Figure 5).

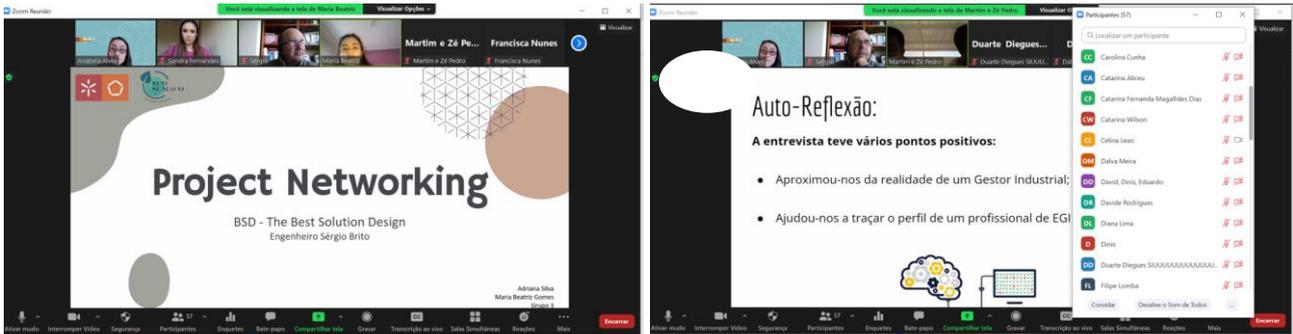


Figure 5. Some snapshots of the zoom session

Main findings from the report and reflections were grouped in four main topics that will be discussed in the following sections: 1) a company database and the connection to IEM professionals for their future contact.; 2) the stimulus of students' capacity of initiative; 3) the students learned how to prepare and do an interview, to communicate, to extract the most important from an interview; 4) the students acquire knowledge where they can work and type of functions they could perform. After the assessment all students obtained a grade higher than 16 (of 20) values.

The two sentences included in the PBL questionnaire that were related with this challenge, and evaluated on a scale from 1 (strongly disagree) to 5 (strongly agree), were:

S1: "The IEM@ProjectNetworking project activity helped me to better understand my professional future."

S2: "I think the weight of the IEM@ProjectNetworking activity (10%) is adequate."

Based on the number of enrolled students, 72% (48 out of 67) voluntarily completed the questionnaire. The main descriptive statistics measures obtained are presented in Table 1, and the students' evaluation distribution for both sentences S1 and S2, by gender, illustrated in Figure 6.

Table 1. Main descriptive statistics obtained for S1 and S2 evaluation (F – female, M – male students).

Descriptive Statistics		S1	S2
n	F	33	34
	M	14	14
	Total	47	48
mean ± s.d.	F	4.88 ± .33	4.24 ± .82
	M	4.57 ± .65	4.21 ± .80
	Total	4.79 ± .46	4.22 ± .81
median	F	5	4
	M	5	4
	Total	5	4
min	F	4	2
	M	3	3
	Total	3	2
max	F	5	5
	M	5	5
	Total	5	5

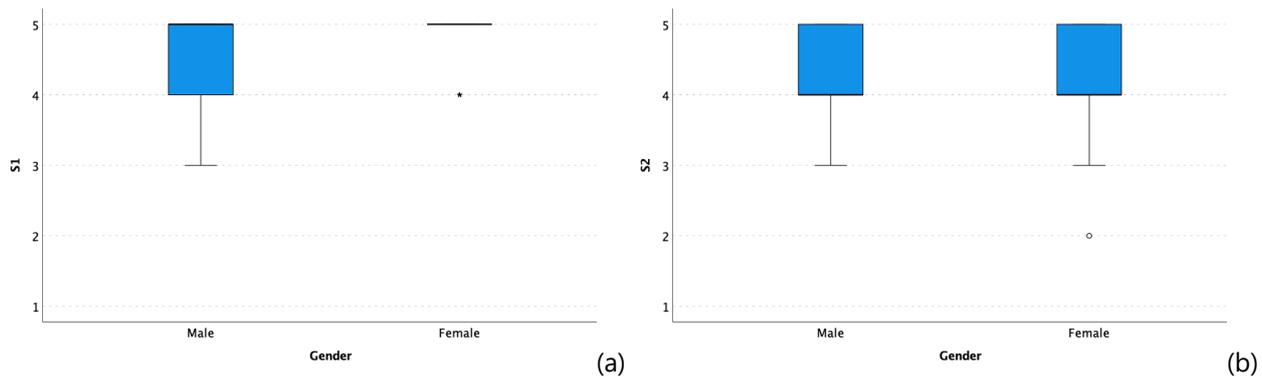


Figure 6. Students' evaluation for sentence (a) S1 and (b) S2, by gender.

Both sentences, S1 and S2, received a positive evaluation, with mean values higher than 4: 4.79 and 4.22, respectively (5 corresponds to strongly agree), with the highest value 5 and the lowest 3. Although slightly differences were observed between the evaluation distribution by gender, namely in sentence S1 with male students with slightly lower values, they are not statistically significance ($U=174.5$, $p>0.05$ for S1, and $U=232.0$, $p>0.05$, for S2). So, students in average considered that the IEM@ProjectNetworking project activity helped to better understand the future professional career.

4.3.1 Database of companies and networking expansion

As referred, 33 interviewes were conducted by students in groups of two, in a total of 37 companies (some students decided to conducted more than one interview and four interviewees were from the same two companies). These companies included international and national companies, small, medium-sized companies (SME) and large companies. Companies were from different sectors: textile, shoes, software development, eletronic components, comercial organizations, cooperatives among others. The interviewees belong to the following list of the companies:

- | | | | | |
|-----------------------------------|-----|--|-----|---------------------|
| 1) PROEF | 13) | Marley Spoon | 24) | Tiajo |
| 2) Farfetch | 14) | BOSCH | 25) | Leiper |
| 3) BSD - The Best Solution Design | 15) | FORteams LAB | 26) | Paul Stricker |
| 4) Fermir | 16) | Gewiss | 27) | Continental |
| 5) ACCO Brands Portuguesa | 17) | Grupo M | 28) | BorgWarner |
| 6) Bysteel (DST group) | 18) | Textil Manuel Gonçalves Sa- Automotive | 29) | Amkor |
| 7) Jordão Cooling Systems | 19) | AICEP | 30) | Off Spin |
| 8) BytePitch | 20) | Custódio Castro Lobo | 31) | Valerius têxteis SA |
| 9) Aldo Shoes | 21) | WIM | 32) | Caixindu |
| 10) Bysteel (DST group) | 22) | Cooperativa Agrícola de Boticas | 33) | LASA |
| 11) GreenPelts Tannery Lda | 23) | AMOB | 34) | GKN |
| 12) Leica | | | 35) | Texteis Penedo |

All addresses and emails from the companies and interviewees were collected for future contacts. This interaction was also positive to strengthen the connection between the companies and the academy, as students played the role of academic ambassadors, fostering opportunities for future collaborations in terms of research and development activities. This networking with the companies also allow to the teachers to know a little more about perspectives of employers regarding the Industrial Engineers competencies.

It is worth emphasising that the process of contacting the company was the responsibility of the students. Some through a family member who knew an engineer and suggested contact or through conversations between them (students). Some of the interviewees are former students of the university and of the same IEM degree.

4.3.2 Stimulus of students' capacity of initiative

Related to the stimulus of students' capacity of initiative, all students developed this capacity. They were capable of contacting an engineer through their closer contacts (family, friends, among others) or someone

they knew and heard in university events or explore other possibilities. It is important to highlight that some pairs described the interviews in the team blog. Figure 7 presents some snapshots of two team blogs, where they described the whole process of conducting the interview .



Figure 7. Extract of two teams blogs snapshots of the interviews' description

Besides a proactive attitude, students developed other transversal competences such as communication competences and organizational behaviour awareness. Although students had an interview guide with questions to support their interview, students also had to deal with unforeseen situations, which led them also to develop the competence of adaptation to new situations, problem solving and resilience in order to proceed successfully with their objectives for this task.

4.3.3 Knowledge to do and interpret an interview

All students followed the semi-structured interview guide and summarized the interviews conducted very well. This was verified by the authors of the paper after hearing and seeing the videos. Also, students were capable of synthesizing the most important contents and recall the interviewees' advices during the oral presentation, for example: *"Do not forget that you work with the people and for the people. It is not forcing processes that will change anything, it is with management by example"*.

4.3.4 Awareness of their professional practice

Through their reports, students realized what it means to be an Industrial Engineer, an idea for an IEM profession and how diverse and broad it could be. All knowledge areas discussed in the introduction were exposed by the interviewees. It was a positive discovery for students, who were amazed by all the professional areas in which they can enrol in their future.

This challenge was even more relevant for students to realize how important the information systems are for modern organizations. Industrial Engineers, who frequently assume the leadership of industrial departments, and even top management positions in the case of industrial SMEs, are often called to specify user requirements related to the need for the implementation of new strategic business evolutions in their organizations' information systems. The students' answers provided for the point 7 (Production Information system) of the interview guide were assessed by the teacher of the Computer Programming I course who established a set of user requirements to be fulfilled by the information system and software to implement in the enterprises of their projects of IPIEM1. In comparison to the two previous editions of PBL (2019 and 2020), the task related to Computer Programming I course, in the present year, was accomplished with more pertinent and valuable content, which confirm the positive contribution of the interviews undertaken by the students in the fulfilment of the IEM@ProjectNetworking challenge.

5 Conclusion

This paper presents the main findings of the challenge given to freshman IEM students. According to them, this experience was very rich and useful, allowing them to have a better look at their future professional career.

Based on students' feedback during and after the oral presentation and also on the analysis of results obtained from part of the PBL questionnaire, it was possible to state that, despite some difficulties, as mentioned in section 4.3, it was a worthwhile challenge. Better time management and teamwork of teachers and students continues being the best solution to overcome the difficulties. This is also evidenced by students' good performance, comments and reflections in the IEM@ProjectNetworking report. It was also clear that students enjoyed the activity very much and listened carefully to the advice from the interviewees and, through the experiences lived in the first-person, students easily learned some lessons.

This experience is also relevant for first-year students as they can achieve greater confidence about their professional future, at an early stage of their academic degree. The experience is significant, useful, and impacting for students. Along with the PBL approach, this experience brings forward the meaning of “learning by doing” in the sense that students are actively engaged in the process of their own learning and development.

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Learning Assessment in a "Theses Debate"

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Abstract

In this scenario of constant expansion of digital information technologies, education saw significant opportunities to review its transmissive practices, generally limited by physical spaces that restrict communications and by the preponderance of analogic pedagogical resources. As an alternative to the use of this new scenario, we conceive a theoretical-methodological framework for the proposition of new active methodologies, which we call Pedagogical Architectures. We define them as structuring supports for learning, performed from the confluence of different components: strategy constructivist, digital technology (software, internet, artificial intelligence, and others), and flexible design of time and space. Although we can practice constructivism, at different levels of teaching, without the use of digital communication technologies, the introduction of these opens new learning possibilities, facilitating the interaction of students with the environment, with the objects of study, with their peers, and teachers. In addition, it favors the resignification of the notions of time and space. With the internet, we interact with objects and people, synchronously or asynchronously, geographically distributed, on a planetary scale. In this study, we experimented with the Pedagogical Architecture Theses Debate. We carried out the study, with 22 students of a doctoral program in Informatics in Education, in a Brazilian public university. We aimed to promote the knowledge construction cooperatively, with the support of a collection of testimonies on the topic Applications of information technology in education. Based on the students' prior knowledge, we held a collective debate in small groups, organized in successive stages of deepening and resignification. We realized the evaluation of learning through the analysis of the textual productions of the individuals, considering different stages of the debate, based on a list of categories created for this purpose. The results showed that the architecture reached its objective, supporting the reconstruction of knowledge.

Keywords: Active Learning; Pedagogical Architectures; Educational Technologies

1 Introduction

Use of active methodologies in the learning process emerged on the international scene in the first half of the 20th century, based on different theoretical contributions, including the works of Dewey (1930), Piaget (1953, 1971) and Vygotsky (1978). Some important elements are present in these contributions, of which we highlight: a) the subject does not acquire knowledge from a passive reception of the information presented to him, it is necessary to build new mental structures from the interaction with the world; b) social interaction is important to share different perceptions with other subjects and, c) It is not enough to know the world as it is at the moment, it is necessary to develop our intellect to produce innovations.

Regarding this last element, let's see what Jean Piaget says.

[...] The invention proper to the experimental spirit and to deduction only becomes rational if it is regulated thanks to the norms of objectivity and logical coherence, and these norms only take on a living value if they are applied to a constructive activity. [...] Piaget (1998)

The theoretical contributions presented above deal with the process of knowledge construction by individuals. However, to migrate from transmissive teaching to a constructivist practice, we still need to develop adequate pedagogical approaches. For the elaboration of constructivist proposals, we need to think about new pedagogical resources, new ways of organizing the school space, and the availability of technological solutions to favor interactions.

The organization of the school space is still restricted to physical spaces between four walls. However, the use of personal digital equipment has become part of the school scenario, giving opportunity to student production, using different media shared from geographically distributed workstations. Notably, in the context

of COVID-19 pandemic, school activities were carried out remotely, in all places where Internet access was available. However, this was not the reality of many developing countries.

Design and production of tangible teaching materials is too expensive both for the cost of production and for obsolescence, which has been attenuated using digital resources, allowing teachers to adopt different media instead of more conventional and expensive ones. In addition, cooperative development of resources, including methodologies, by a network of teachers and other professionals has also been carried out in an international movement led by UNESCO (Elder, 2019).

However, there is an obstacle to be overcome for these new materials meet the principles of active learning: a methodological basis. Our research group has been working in this direction and, in recent years, we have developed a framework to support the design of new proposals for active methodologies, which we call Pedagogical Architectures (Menezes and Aragón, 2018). In this article we present an experiment supported by an active methodology called "Theses Debate", built within this Framework. The results indicate that this proposal can contribute to the construction of knowledge in an active and cooperative approach.

2 Pedagogical Architectures

According to genetic epistemology (Piaget, 1971), learning results from the restructuring of a subject's network of meanings based on a process of rebalancing. In this sense, it is necessary for the subject to enter into cognitive conflict, which can be understood as an impossibility of explaining a fact of reality with his current knowledge. Rebalancing is then sought using the metacognitive operations of assimilation and accommodation. Conflicts can occur from the subject's interactions with the objects of the field of study, whether physical or conceptual, or through social interaction, which can be understood as a mediation process. Mediation can be carried out through interaction between students, called distributed mediation, or with the participation of teachers (Aragón, 2016). In view of our intention to make use of digital technologies, notably communication networks and artificial intelligence, the framework we propose already considers the possibilities of communication and mediation made possible by these two elements.

In line with these principles, we define a Pedagogical Architecture as a methodological framework articulated by the following components: the domain of knowledge; educational goals; students' prior knowledge of a certain domain; the problem-oriented interactionist dynamics; distributed pedagogical mediations; procedural and cooperative assessment of learning and support of digital technology (Menezes, Castro and Aragón, 2020).

2.1 Theses Debate

The practice of debate constitutes a socialization process that serves the development of citizenship and thinking (Parrat-Dayán, 2007). To support this process in education, one of the alternatives is to act in the perspective of promoting the exchange of points of view, which calls on students to position themselves in relation to others, but, at the same time, remain open to others views. The Theses Debate architecture is part of this perspective, constituting itself as a structuring framework for the construction of knowledge.

In this activity, the construction of knowledge is triggered by a set of statements, raised with the students and/or collected from the paradigmatic literature. From that point on, we can ask the participants to take a stand, whether they agree or not, followed by an argumentative justification. Subsequently, the arguers assume the role of reviewers and each one must analyse the arguments of one or more of their peers. This review does not seek to oppose the participants' conceptions, but to present problematizations so that each one can express their position more clearly. Once the reviews are completed, the participants return to their arguments and present replies to their reviewers, responding to the problems received and providing clarifications on points raised by the reviewers. Now, based on the reviews received from their reviewers, on the arguments and replies of their reviewers, each participant is invited to review their position and rewrite their arguments.

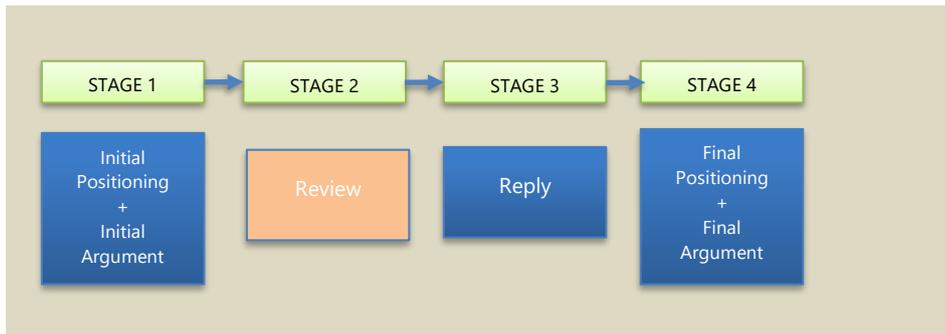


Figure 1. Development Flux in Theses Debate

3 The experiment

We have continuously used the Theses Debate pedagogical architecture in different disciplines, mainly in postgraduate (MSc/PhD) courses, in the training of professionals for the use of digital technologies in education. The experiment we present in this article deals with the application of this educational technology during the first semester of 2020, in the context of the Subject "Cooperative Learning in Digital Context". The choice was made because it was an edition with a greater number of students, which provides a greater diversity of situations and because it is the first opportunity to use it during the COVID-19 pandemic.

Twenty-two students (15 women and 7 men) from a doctoral program in Informatics applied to Education participated in that edition. The domain profile of the participants was: Education (5), Science Teaching (3), Mathematics Teaching (2), Computing (4), Communication (1), Administration (1), Arts (2) and Educational Technologies (4).

The discipline's principle is the development of its themes from active methodologies. Thus, to present the Theses debate Architecture, discuss its foundations and analyse its contributions to the learning process, we started with a debate on three theses covering "the use of digital technologies in education". Three theses were selected by participants from a list previously prepared by the teacher based on topics considered relevant in the context of the use of digital technologies in educational activities, according to the list presented in Table 1.

Table 1: Theses used in the experiment

<p>Thesis 1: Working in a collaborative environment is not the same of standardizing speech or thinking, but rather to bring together points of view in favor of everyone.</p> <p>Thesis 2: Using the internet, students can share results obtained in a problem to their colleagues, in a process that shortens the resolution of the work.</p> <p>Thesis 3: Digital games are addictive and distract students from learning; however, building games mixed with math challenges can increase students' interest.</p>

In agreement with the students, a schedule was prepared and provided 3 days for the first stage (position and initial argumentation and 1 day for each of the four subsequent stages.

The computational support used was based on individual debate pages, one per participant, available on an online site, where participants had online access. Each column on the page should only be edited in the time interval defined in the schedule by the participants involved in the page.

Argumentator:						
Reviewer 1:						
Reviewer 2:						
Thesis	Stage 1		Stage 2	Stage 3	Stage 4	
	Initial positioning	Initial Argument	Review	Reply	Final positioning	Final Argument
Working in a collaborative environment is not synonymous with standardizing speech or thinking but bringing together points of view in favor of everyone.			R1			
			R2			
Using the internet, students can pass the results obtained in a problem to their colleagues, in a process that shortens the resolution of the work.			R1			
			R2			
Digital games are addictive and distract students from learning; however, building games mixed with math challenges can increase students' interest.			R1			
			R2			

Figure 2: Digital Debate Sheet

4 Argument Analysis

The analysis was carried out using a qualitative approach and focused on understanding the potential of the Theses debate Pedagogical Architecture (AP) to promote cooperative learning.

The data collection allowed us to propose and proceed with the categorization of the arguments developed by the 22 students, for each of the three theses, as well as observing the changes between the initial arguments (step 1) and the arguments elaborated after the stages of review and reply.

To carry out the analysis of the arguments, we defined 10 categories based on the justifications of the students' positions in relation to the three theses in the initial stage (categories C1 to C4) and in the final stage (categories C5 to C10) of the Pedagogical Architecture. The categories are presented in Table 2.

Table 2: Categories of arguments

Initial Arguments
C1-Badly developed initial arguments, based on opinions and/or personal experiences (or that only repeat the thesis);
C2- Arguments developed based on interpretations of concrete evidence;
C3- Arguments based on theoretical/methodological contributions that support them;
C4- Arguments that bring contradiction with the positioning.
Final Arguments
C5- Arguments that repeat the initial ideas, without enrichment;
C6- Arguments that consider the ideas expressed by the reviewers and bring enrichment;
C7-Arguments enriched with new elements, regardless of the ideas expressed by the reviewers;
C8-Arguments that support new positions considering the ideas expressed by the reviewers;
C9- Arguments that support new positions regardless of the ideas expressed by the reviewers;
C10- Arguments that bring contradiction with respect to the positioning.

The categorization of the arguments, considering the categories in Table 2, allowed the elaboration of Table 3, which aims to present an overview of the arguments expressed by the subjects, considering each of the three theses, in the different stages of the cooperative work "Thesis Debate".

Table 3: Argument distribution by student category

Students	Initial argument (categories C1-C4)			Final arguments (Categories C5-C10)		
	Thesis 1	Thesis 2	Thesis 3	Thesis 1	Thesis 2	Thesis 3
S01	C1	C1	C1	C6	C6	C8
S02	C1	C1	C2	C6	C6	C5
S03	C3	C2	C3	C6	C6	C6
S04	C1	C1	C1	C8	C8	C8
S05	C1	C1	C1	C10	C6	C6
S06	C2	C2	C2	C5	C5	C5
S07	C2	C2	C1	C6	C8	C7
SC8	C2	C2	C3	C7	C6	C5
S09	C1	C4	C1	C6	C8	C9
S10	C2	C1	C2	C6	C6	C5
S11	C1	C1	C1	C8	C6	C8
S12	C4	C1	C2	C5	C5	C6
S13	C3	C2	C2	C6	C6	C6
S14	C3	C2	C2	C6	C6	C8
S15	C2	C2	C2	C6	C6	C6
S16	C2	C1	C1	C6	C6	C5
S17	C1	C2	C1	C6	C6	C8
S18	C1	C1	C1	C6	C6	C6
S19	C1	C1	C3	C6	C6	C7
S20	C1	C1	C1	C6	C6	C6
S21	C2	C3	C2	C5	C8	C6
S22	C1	C1	C2	C6	C6	C6

Based on Table 3, we prepared Tables 4 and 5, which allow us to observe the distribution of arguments by categories, considering the three theses (Thesis 1, Thesis 2, and Thesis 3) adopted for the development of Pedagogical Architecture. In each of the stages, 22 students argued justifying their positions in front of the theses, resulting in a total of 66 categorized arguments in each of the stages.

Table 4: Category distribution of arguments by thesis (initial stage)

Initial arguments	Thesis 1	Thesis 2	Thesis 3	Totals
C1-Badly developed initial arguments, based on opinions and/or personal experiences (or that only repeat the thesis);	11	12	10	33
C2- Arguments developed based on interpretations of concrete evidence;	7	8	9	24
C3- Arguments based on theoretical/methodological contributions that support them;	3	1	3	7
C4- Arguments that bring contradiction with the positioning.	1	1	0	2

Looking at Tables 4 and 5, we can say that most students (15 of the 22 students) started the AP, using poorly developed arguments, based on opinions and/or personal experiences or that only repeated the thesis. In this category (C1) it is possible to classify 33 justifications of positions, in at least one of the theses, by 15 students (6 students argued this way for the three theses, 6 students for 2 theses and 3 students for 1 thesis).

Arguments based on interpretations of concrete evidence (C2) were used to justify the positions of 16 students in 24 theses (2 students used this argument for 3 theses, 6 used it for 2 theses and 6 for 1 thesis). The arguments based on theoretical-methodological contributions (C3) were used by 7 students to justify their positions in 7 theses (6 subjects used this form of argument, none of them used to justify their position in all theses and only 1 student used argumentation to justify 2 theses).

Table 5 presents the distribution of the number of arguments per thesis.

Table 5: Category distribution of arguments by thesis (final stage)

Final arguments	Thesis 1	Thesis 2	Thesis 3	Totals
C5- Arguments that repeat the initial ideas, without enrichment;	3	2	5	10
C6- Arguments that consider the reviewers' ideas and bring enrichment;	15	16	9	40
C7- Arguments that are enriched with new elements, regardless of the ideas expressed by the reviewers;	1	0	2	03
C8- New arguments that support new positions, consider the reviewers' ideas;	2	4	5	11
C9- Arguments support new positions, regardless of the ideas raised by the reviewers.	0	0	1	01
C10-Arguments that bring contradiction with the positioning.	1	0	0	01

Regarding the students' arguments, in the final stage, we identified a prevalence of arguments that were enriched from the debate with the reviewers. In category C6, we identified 18 students who modified their arguments to support at least one of the three theses, totaling changes in the arguments of 40 of the 66 theses.

Changes in the arguments were identified, linked to a new position (agree, disagree, or partially agree), which were motivated by exchanges with reviewers who pointed out weaknesses in the initial argument and/or raised new arguments for the colleague, as well as their reflections from the contact with the arguments of colleagues.

Category C7 was identified in the arguments of 3 students. Each of the students modified their arguments in 1 of the 3 theses.

Of the 22 students, 7 subjects maintained their arguments in at least 1 of the 3 theses, that is, they repeated the initial arguments and positions (C5). Only one student finished the AP maintaining the same arguments for the three theses. This student, in the assessment space, expressed not having clearly understood the debate. Still, 1 student changed his position and arguments without the influence of exchanges with the reviewers (C9) and 1 student, in one of the theses, presented a contradictory position with his own arguments (C10).

5 Discussion and Final Remarks

The first result to be emphasized refers to the potential of Theses Debate to promote active and collaborative learning, considering the changes in the arguments related to the enhancement of ideas and changes in positions regarding the theses debated.

The experiment allowed us to observe qualitative changes in the arguments (due to the need to express them) and the advances in the understanding of colleagues' ideas and study on the theses under debate. These changes were predominantly due to improvement of initial arguments, even when there was no change in the position (agreement, disagreement, and partial agreement). In addition to those improvements, which were more frequent, changes in positioning were also identified, with the elaboration of new arguments, predominantly motivated by interactions with the reviewers, but also because of reflections after the first positioning. In all these cases, advances in the consistency of the arguments were evidenced.

Positions and arguments about thesis 1 (20 of the 22 students in the final stage agreed) and thesis 2 (18 of the 22 students in the final stage) showed us that they consider cooperative work relevant for learning. They understand that cooperative learning is not reduced to an abbreviation of work, but to a construction that takes place through the coordination of different points of view.

Considering students' evaluations, we can say that the experience of collaborative work reinforced the importance of exchanges in active learning. The review stage proved to be relevant for the improvement of arguments, with advances both in consistency and expression of ideas as well as development of critical thinking.

Regarding the work dynamics and use of the virtual environment, the evaluations showed that it was positive, allowing more activity and protagonism from students. Most students considered that the environment was adequate to support the architecture, although three students found some initial difficulties in using it. Some students expressed that they perceived possibilities of using Theses Debate in their work contexts, with the necessary adjustments according to student age and pedagogical objectives. They mentioned, for example, the adoption of different theses for each subject and division into groups based on the positions favoring the discussion between those who agreed and those who disagreed.

Regarding criticisms and suggestions, most students expressed that they would have carried out interactions for longer so that they would become more familiar with work dynamics and would have more time for reflection. Some students suggested that, in future AP applications, more material should be made available before all stages; the introduction of a new specific stage for online discussions by the entire group; and further time to the establishment of connections supported by a theoretical framework. It was also suggested the use of a specific (custom-made) environment for Theses Debate.

As a result of the authors' findings and suggestions of the students, an updated version of a specific environment for Theses Debate is being produced, and will have new features to automate the organization of stages and facilitate teacher mediation. In addition, new stages like search for approximations and differences between arguments and formation of groups for the elaboration of argumentative texts are to be implemented. These improvements will be the subject of future work.

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Promoting assessment as learning in PBL: findings from blogs created by first year engineering students

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Abstract

This paper aims to present findings from first year engineering students involved in a Project-Based Learning (PBL) approach developed within the first cycle degree of Industrial Engineering and Management (IEM) – University of Minho, Portugal. Student assessment in PBL includes both formative and summative assessment, with a variety of different methods and purposes. One of the assessment methods in this PBL approach is the creation of a blog by each project team with the purpose of providing student reflection of their work on a regular basis. The blog allows students to share evidence of the project journey, with particular focus on the student's learning process. This idea is aligned with the concept of assessment as learning, where students are able to learn about themselves as learners and take responsibility for their own learning and monitor future directions. Based on the analysis of both quantitative and qualitative results from an online survey applied to students and the content analysis of each of the blogs, it is possible to conclude that the assessment task was considered as a positive learning experience for students. Quantitative data from the questionnaire show that the blog was a positive educational tool useful for: i) the organization and dissemination of the project team; ii) the selection of the project content and organization; iii) keeping an up-to-date record of the project's progress; iv) encouraging writing about project content and other curiosities. The qualitative data based on the content analysis of the blogs revealed students' capacity to reflect upon their journey, by critically analysing the feelings, achievements, fears, thoughts, and future plans, throughout the thirteen weeks of the project duration.

Keywords: project-based learning (PBL); student assessment; assessment as learning; blog as educational tool;

1 Introduction

Promoting assessment as a tool for learning is at the core of the higher education agenda (Evans, 2020; Zhang et al., 2019). Far beyond the traditional perspective of assessment as a task that takes place at the end of a unit, designed to confirm what students know and verify if the curriculum goals were met, the concept of assessment has enlarged its perspective to include a type of assessment that is mainly focused on students' learning process and therefore occurs throughout the learning process and is aimed at improving student learning through feedback and self-reflection (Sambell et al., 2012). These ideas are based on what Earl and Katz (2006) identified as the three purposes of classroom assessment: assessment of learning, assessment for learning, and assessment as learning. Each of these forms of assessment entail different assessment purposes, types and methods, as show in figure 1.

Student assessment plays a major role in how students learn, their motivation to learn, and how teachers teach (Earl & Katz, 2006). Assessment promotes awareness of the knowledge, skills, and beliefs that students bring to a learning task, promoting student learning. Learning is also enhanced when students are encouraged to think about their own learning, to review their experiences of learning (What made sense and what didn't? How does this fit with what I already know, or think I know?), and to apply what they have learned to their future learning (Earl & Katz, 2006). This type of assessment is usually used in teaching and learning environments which focus on student centred learning and assessment methods that engage students in meaningful learning. Project-Based Learning (PBL) is one of those approaches (Alves et al., 2021).

One of the characteristics of student assessment in PBL is the diversity of assessment methods and purposes (Fernandes et al., 2012a, 2012b, 2021). PBL approaches include both summative and formative assessment practices. However, the great emphasis that is put in the student's learning process gives formative assessment

a very important role in PBL, as it aims to monitor, guide, improve, support and regulate student learning. To meet this goal, alternative assessment methods, such as rubrics, portfolios, simulations, blogs, etc. are highly recommended.

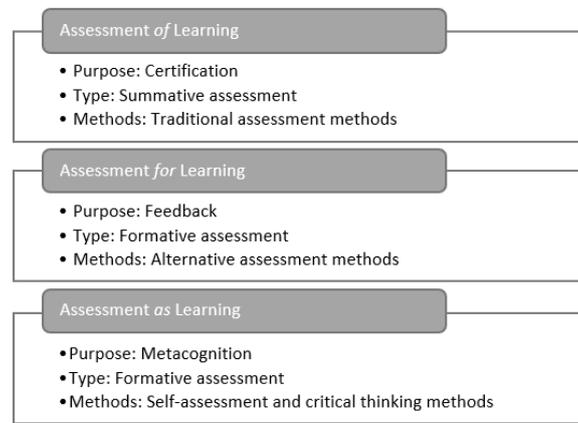


Figure 1: Assessment Purposes, Types and Methods (Fernandes et al., 2021)

Based on this assumption, this paper will present findings from the use of digital blogs in PBL with the purpose of providing student reflection of their work on a regular basis. The blog allows students to share evidence of the project journey, with particular focus on the student's learning process (Alves, Pereira, et al., 2020; Ifinedo, 2017; Jackling et al., 2015; Marinho et al., 2021). This idea is aligned with the concept of assessment learning, where students are able to learn about themselves as learners and take responsibility for their own learning and monitor future directions. Student assessment in PBL recognizes the importance promoting assessment as learning, giving students several opportunities to reflect and take responsibility for their own learning process.

This paper is structured in five sections. This introduction is followed by the PBL approach adopted in IEM. Third section presents the methodology. Fourth section shows the results obtained and, finally, fifth section presents the discussion and final remarks.

2 PBL approach at Industrial Engineering and Management (IEM)

The PBL was introduced in 2004 by a team of teachers of IEM in School of Engineering of the University of Minho (UMinho) (Alves et al., 2020; Lima et al., 2007). Since then, many improvements were implemented, including a formal structure change that introduced formally the Integrated Project of IEM1 (Alves et al., 2014). Nineteen editions were carried out by teams of teachers, tutors and researchers (Alves et al., 2021). A journey of continuous improvement has been carried out every year (Alves et al., 2017; Alves & Leão, 2015).

The cohort of 2021/22 involved more students than in previous years, i.e. 67 students were enrolled at this academic year. These students were organized in eight teams of seven-nine members. Each team had to develop a project in the context of the course Integrated Project in Industrial Engineering and Management I (IPIEM1). Every year the project theme (Moreira et al., 2011) is different and this year teams had to design of a production system to produce a more sustainable packing and should apply the contents learned in the five different courses, presented in Figure 2.

Regime	Curricular Unit
Year 1	
S1	Calculus for Engineering
S1	Computer Programming I
S1	Integrated Project in Industrial Engineering and Management I
S1	Introduction to Economics Engineering
S1	Introduction to Industrial Engineering and Management
S1	Linear Algebra for Engineering

Figure 2. Curricular plan of IEM first-year, first semester, IEM11

Each course has their own assessment methodology that includes a project component. Nevertheless, the contents of each course included in the IPIEM1 is assessed in the presentations, reports, blog, prototypes, that the teams delivered to be assessed. Table 1 shows the milestones of the IPIEM1 and the weight of each deliverable in the assessment methodology. Individual grade of each student is the result of team grade influenced by a correction factor that result from the peer assessment (Fernandes et al., 2009; Fernandes et al., 2020; Uebe-Mansur & Alves, 2018) (90%) and the grade obtained to the IEM@ProjectNetworking (third milestone) (Alves et al., 2013, 2022). As can be seen, the blog is part of the fifth milestone and should be finished until de last day of the project.

Table 1. Milestones (Ms) and weight of each in the assessment

Ms	Week	Deliverable	Weight (%)
1	Week 2	1st presentation	not assessed
2	Week 6	2nd presentation	7,5 (team)
3	Week 8	IEM@ProjectNetworking presentation	10 (individual)
4	Week 11	Preliminary report	25 (team)
5	Week 13	Final report + Prototypes + blog	30 + 20 + 5 (team)
6	Week 14	Final presentation & discussion	12,5 (team)

Each team created a blog, that was regularly presented and discussed by the team members and the tutors and teachers. Table 2 also includes the links to each of the team blogs.

Table 2. Team blogs of IEM first-year students 2021/22

Teams	Team name	Link to the Blogs
1.	KEY	https://keykeepthenvironment.wixsite.com/websitekey
2.	GreenBox	https://grupo2legi1.wixsite.com/website
3.	Eco-Sumaco	https://eco-sumaco.wixsite.com/eco-sumaco
4.	HEARTH	https://grupo4egiuminho.wixsite.com/website
5.	LEAF	https://rosa-gil.wixsite.com/leaf
6.	BioPackage	https://pleg62122.wixsite.com/biopackage
7.	United for Change	https://piegigrupo7.wixsite.com/blog
8.	E-Thinking	https://grupo8piegi.wixsite.com/website

3 Methodology

This paper aims to give answer to the following research questions:

- How do students describe their PBL experience in their team blogs?
- What importance to students give to the blog as a learning tool?
- How do blogs contribute to promote assessment as learning in PBL?

For data collection a questionnaire was used to collect feedback from students at the end of the PBL experience. This questionnaire was organized based on a set of items that explore the way the PBL process was developed

and perceived by students. From the 58 statements/items based a 5-point scale of agreement (1- strongly disagree, to 5- strongly agree), 4 items were selected from the questionnaire to be analysed for the scope of this study. These items are related to the importance given by students to the blog as a learning tool. The items are the following:

- Q14 – useful for the organization and dissemination of the team project;
- Q15 - helps to select, organize and register the contents related to the project;
- Q16 – helps to keep an updated record of the project’s progress; and
- Q17 – stimulated writing (in English) about the contents related to the project and some curiosities.

Besides this analysis, the content of the blogs was also carefully analysed, through the identification of the main categories that relate to the principles of assessment as learning.

4 Results

Based on the analysis of the results from the questionnaire applied to students and the content analysis of each of the blogs, the following section presents the organization of the analysis of results according to the main categories identified in the qualitative and quantitative data. For the quantitative analysis the non-parametric test Mann-Whitney (U) for comparison between the assessment of two independent samples (students gender), after verification of normality by Shapiro-Wilk test, was used. Data were stored in Excel and later analysed with the statistical software SPSS 28.0.

4.1 Student satisfaction with blogs as an educational tool: a quantitative analysis

Data in this study, as previously mentioned, was gathered using four items in the PBL questionnaire that 72% of the enrolled students voluntarily and anonymous filled, and then analysed using statistical methods.

The sample included students from the all teams, however not all the members of each team answered the questionnaire, varied from 50% (in one team) to 88% (in one team). The majority of participant students (70.8%) are female, reflecting the gender balance of the course with 63.2% of female students. The main descriptive statistics measures obtained based on students’ perceptions for the four items Q14, Q15, Q16 and Q17 are presented in Table 3, total and by gender.

Table 3. Main descriptive statistics obtained for Q14, Q15, Q16 and Q17 students’ perceptions (F – female, M – male).

Descriptive Statistics		Q14	Q15	Q16	Q17
n	F	34	34	34	34
	M	14	13	13	14
	Total	48	47	47	48
mean ± s.d.	F	4.03 ± .83	4.03 ± .63	4.29 ± .72	4.50 ± .62
	M	4.07 ± .83	4.08 ± .76	3.69 ± .85	3.71 ± 1.14
	Total	4.04 ± .82	4.04 ± .78	4.13 ± .78	4.27 ± .87
median	F	4	4	4	5
	M	4	4	4	4
	Total	4	4	4	4
min	F	2	3	3	3
	M	3	3	2	2
	Total	2	3	2	2
max	F	5	5	5	5
	M	5	5	5	5
	Total	5	5	5	5

Generally, quantitative data from the questionnaire show that the blog was a positive educational tool useful for: i) the organization and dissemination of the team project (mean=4.04); ii) the selection of the project

content and organization (mean=4.04); iii) keeping an up-to-date record of the project's progress (mean=4.13); and iv) encouraging writing about project content and other curiosities (mean=4.27).

Notwithstanding the overall positive assessment of the blog, when the analysis by gender was made, some differences between genders have been uncovered (Figure 4). The differences statistically significant encountered between genders were in the two items Q16 and Q17, with female student assessing these two items with a higher mean ($U=135.0$, $p<.05$, for Q16 and $U=142.5$, $p<.05$, for Q17). That is, regarding keeping an up-to-date record of the project's progress (Q16) and encouraging writing about project content and other curiosities (Q17) female students attributed more importance. Also, Figure 3 illustrate the students' assessment distribution for both genders regarding item Q17 where the highest difference between genders were occurred.

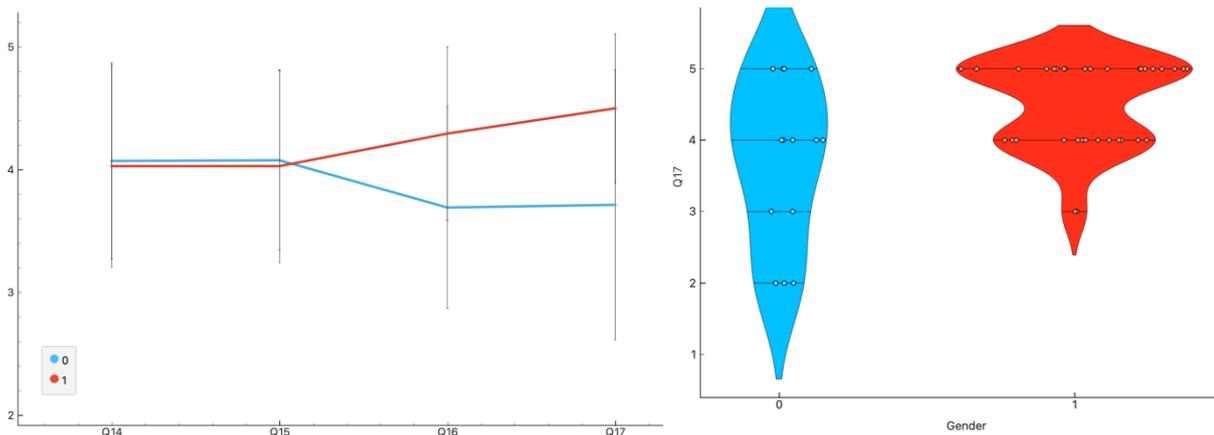


Figure 3. Students' assessment by gender: (a) mean values for all items and (b) distribution for Q17 (blue male and red female students).

To some extent, this positive results seems to be in line with a previous preliminary study regarding gender difference in peer assessment, where female students obtain peer assessment higher marks in comparison with their male colleagues (Alves, Moreira & Leão, 2017) and that it is usually the female students who develop writing tasks and keep the tasks up to date.

4.2 Promoting student self-reflection through blogs: a qualitative analysis

The qualitative data based on the content analysis of the blogs revealed students' capacity to reflect upon their journey, by critically analysing the feelings, achievements, fears, thoughts, and future plans, throughout the fifteen weeks of the project duration. The following sections reveal, through examples extracted from the blogs, students' capacity of self-reflection regarding their team roles and the weekly meeting reports.

4.2.1 Team member characteristics and roles

The content of the blogs reveal that the teams focused on presenting information about their initial expectations and motivations in regard to the project and also identifying their preferred team role, according to the nine roles considered in the Belbin test (Figure 4). This helped to characterize the team as whole.

"We are a team constituted by 8 members of the engineering and industrial management at the University of Minho, willing to spread awareness about environmental and sustainability causes".

"Eco Sumaco is the result of the hardwork of 8 dedicated Industrial Management and Engineering students in the University of Minho".

"During the third week, we did some important things for our project. We had to complete the so called "Belbin tests", which were useful to make us understand the role of each member of the group. Also, besides the natural organisation that we had to do in all of our social media to keep it updated, we were able to be in a position where we would have some individual feedback in terms of our contribution to the project, by doing the peer evaluation."

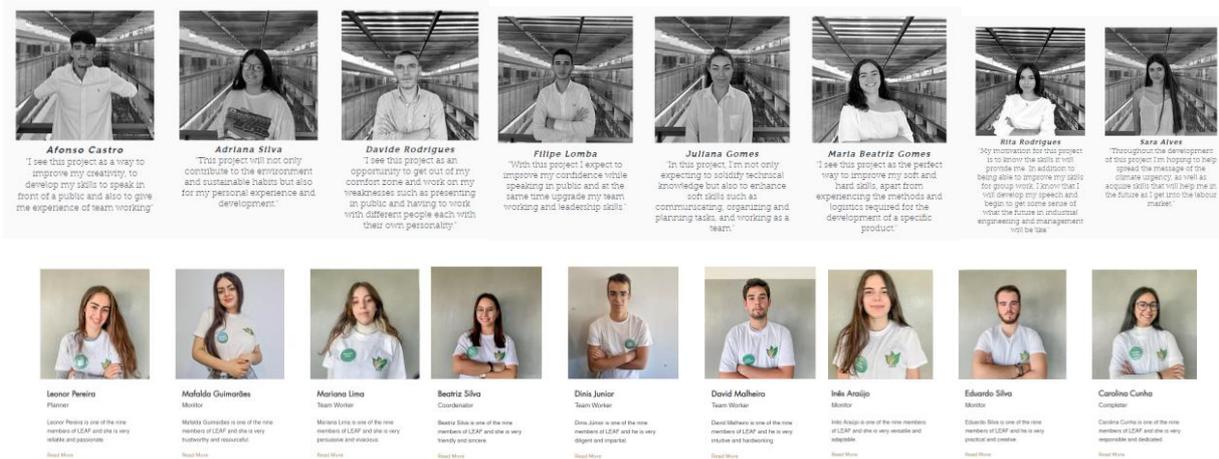


Figure 4. Examples of how teams presented each team member and their roles in the project

Students also expressed, at an initial phase of the project, their expectations and motivations in regard to the project. This reflection shows how students related the objectives of the project with the development of their individual competences. For students to be able to improve, they must develop the capacity to monitor the quality of their own work.

"My motivation for this project is to know the skills it will provide me. In addition to being able to improve my skills for group work, I know that I will develop my speech and begin to get some sense of what the future in industrial engineering and management will be like."

"Throughout the development of this project I'm hoping to help spread the message of the climate urgency, as well as acquire skills that will help me in the future as I get into the labour market."

"With this project I expect to improve my confidence while speaking in public and at the same time upgrade my team working and leadership skills."

"In this project, I'm not only expecting to solidify technical knowledge but also to enhance soft skills such as communicating, organizing and planning tasks, and working as a team."

"I see this project as the perfect way to improve my soft and hard skills, apart from experiencing the methods and logistics required for the development of a specific product."

"I see this project as a way to improve my creativity, to develop my skills to speak in front of a public and also to give me experience of team working"

"This project will not only contribute to the environment and sustainable habits but also for my personal experience and development."

"I see this project as an opportunity to get out of my comfort zone and work on my weaknesses such as presenting in public and having to work with different people each with their own personality."

4.2.2 Weekly meeting records

These weekly reports reveal student's thinking about his/her learning process and the strategies or mechanisms that were used to adjust and advance in the project (Figure 5). When students reflect on their own learning and need to communicate it to others, as they did in their blogs, they are intensifying their understanding about a topic, their own learning strengths as a team and the areas in which they need to develop further.

"Today was a very special day for the team. We gather for the first time and it was awesome to get to know each other within the work context. We are looking forward to the change. What about you? Are you with us?"

"Greeting to all readers and welcome to our very first weekly report about our project. Firstly, we met our student advisor, Margarida Vasconcelos, that introduced us to many resources that we could use, as a team, from communicating to sharing media files and more. Afterwards she briefly spoke about her experience as a student, working on a project based on similar bases as ours in past years. Subsequently, we got to know our mentor Florentina Abreu that discussed what possible paths we could go to. On the second meeting, we split as pairs (after doing the personality test) working on many areas such as blog pair, research pair, presentation pair and

script pair. Here, we divided tasks, organized and built our very own work schedule as well as searching some topics about our project". (G2)

"Like every journey ever, this one has come to an end. It was a pleasure, and a big one. When we started this project the only thing we knew was our main goal, the development of some sort of sustainable packaging. We had no idea with who we were going to work, we had no idea how to even work in an "company", this was something new. The first weeks were rough, we were experiencing something outrageously out of our comfort zone. We had a chance to meet everyone involved in the project and get to know our future colleagues. This was the beginning of HEARTH. HEARTH, the combination of the words "earth" and "heart" was our little invention. A company that would create a sustainable package for cakes and little pastry items. It was exciting, it was stressful, it was everything. Every emotion possible, we felt it. From panic to laughter, from anxiety to relief, it was the full package. This was a chapter in our lives that none of us will ever forget. Our hearts are nothing but filled with joy and love after this semester of absolute madness. We loved it. There is nothing more to say. We want to thank everyone involved in the making of HEARTH, our tutors, our teachers, and of course our amazing team. Without them this would be even crazier than it was. Thank you so much, see you soon, stay safe and remember, Keep earth's heart beating. HEARTH."

"After 3 long months of hard work and dedication, we reached the end of our final project. This project has been a true challenge in so many ways that we couldn't even imagine. It has been a pleasure to complete all our given tasks from the various CUs, where we saw the practical use of our theoretical knowledge, improving not only hard skills but many soft skills, one of the many goals we had predicted. In the beginning we had no idea this project would have this sort of dimension, but we are glad that we were able to learn so much about teamwork, leadership, initiative and have a taste of what being an industrial engineer would feel like. In general, we are thankful for the proposed project, and we would like to thank everyone involved in it, including our teacher-mentor, Maria Florentina Abreu, our student-mentor, Margarida Vasconcelos, and all our CUs teachers! We hope you could learn from us to always think outside the box, see you another time. GreenBox".

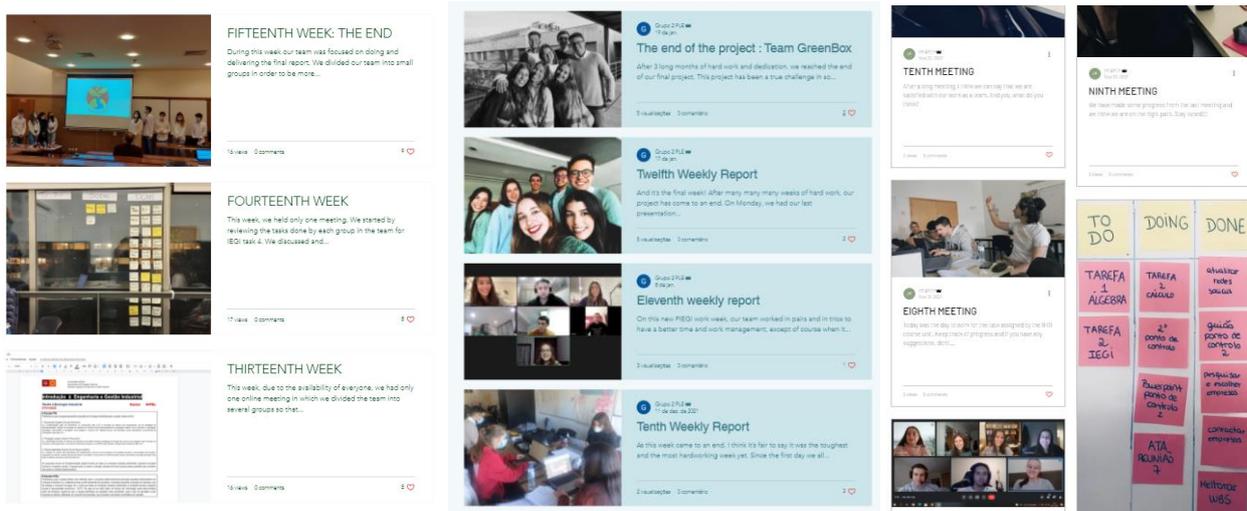


Figure 5. Examples of strategies or mechanisms that students adopted to adjust and advance in the project

5 Final remarks

This paper presents findings about the use of blogs to promote assessment as learning in a PBL context, carried out within an IEM program. The creation of a blog by the project teams as one of the assessment components of the PBL approach has allowed the first-year engineering students to share the development of the project, focusing especially on the team members' learning process and promoting the reflection and self-assessment about their work throughout the thirteen weeks of the project. According to the analysis of both quantitative and qualitative results, it was possible to address the research questions that guided the development of this study.

The first research question refers to the student's experience with their team blogs. Based on the results of the quantitative data from an online survey, the majority of students expressed a positive judgement about the blog as a useful educational tool for: i) the organization and dissemination of the project team; ii) the selection

of the project content and organization; iii) keeping an up-to-date record of the project's progress; iv) encouraging writing about project content and other curiosities.

Moreover, the second research question addresses the importance the students give to the blog as a learning tool. Based on the abovementioned results of the quantitative data, it is possible to conclude that, based on the overall analysis, the students value more the fact of being able to keep up-to-date record of the project's progress, as well as, the opportunity to write in English about project content and other curiosities. However, if the analysis is carried out by gender, it is possible to perceive that female students value more these two points, while male students attribute more importance to the usefulness of the blog in the organization and dissemination of the team project, as well as, the ease that the blog gives to organize and register the contents related to the project.

Finally, the last research question intends to understand how blogs can contribute to promote assessment as learning in PBL context. Thus, the qualitative data that resulted from blogs' content analysis, allowed to conclude that this learning tool promotes students' capacity to reflect about their work and journey, showing a strong sense of criticism when analysing their feelings, weaknesses, achievements, strengths and future plans during the development of the project.

These conclusions are aligned with the concept of assessment as learning, that aims to promote an environment where students are able to learn about themselves and take responsibility for their own learning process, while developing abilities to evaluate their own progress and direct their own learning. For graduates and professionals, the most important assessment is self-assessment. Our students should be helped to develop appropriate dispositions, attitudes and skills (McDowell & Sambell, 2007; Sambell et al., 2012).

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The student journey in PBL: using individual portfolios to promote self-reflection and assessment as learning

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Abstract

This paper aims to present findings based on students' journey within a Project-based learning (PBL) experience, with particular emphasis on the development of an individual portfolio by students, as part of the assessment process. The PBL project involved three curricular units (Research Methods and Techniques II, Ethics and Education and Sociology of Education), from the field of Education Sciences, integrated in the first year of the study plan of the Social Education degree programme at Portucalense University, Portugal. This paper describes student assessment within this educational approach, including both formative and summative methods. It calls attention to the concept of assessment *as learning*, which can be understood as a process where students are able to learn about themselves as learners and take responsibility for their own learning and monitor future directions. One of the assessment methods included in the PBL approach is the development of an individual portfolio with the purpose of enhancing student self-reflection and assessment of their work on a regular basis. The portfolio allowed students to share evidence of the project journey, with particular focus on the student's learning process. The students were provided with general guidelines to develop their portfolio, but the flexible nature of this educational resource allowed students to record and highlight their individual and team contributions in a very creative and personalized way. The analysis of qualitative data from the individual student portfolios reveals student self-reflection on individual achievements, project milestones, teamwork skills, impact of teacher feedback, celebration moments, amongst others. Implications of these findings for PBL assessment practices will be discussed further in the paper.

Keywords: project-based learning (PBL); student assessment; assessment as learning; individual portfolios

1 Introduction

Project-based learning (PBL) is an educational approach which focuses on student-centred learning, the articulation between theory and practice and the development of student skills (Powell, 1999; Powell & Weenk, 2003). It has been widely used in higher education programs to improve student engagement, promote active learning and provide significant learning experiences (S. Fernandes et al., 2014; Lima, R. M., Dinis-Carvalho, J., Sousa, R. M., Alves, A. C., Moreira, F., Fernandes, S., & Mesquita et al., 2017; Prince, 2004).

Student assessment in PBL differs from traditional assessment. It focuses on assessment as an integrated process, with the purpose of improving student learning through relevant feedback and self-reflection (S. Fernandes et al., 2012; S. Fernandes, Alves, et al., 2021; S. R. Fernandes et al., 2010; M. I. R. Ortigão, D. Fernandes, 2019). Far beyond the concept of assessment *of learning*, student assessment in PBL emphasizes the concept of assessment *for learning* or assessment *as learning*, which can be understood as a process where students are able to learn about themselves as learners and take responsibility for their own learning and monitoring future directions (Earl & Katz, 2006; Sambell et al., 2012).

Student portfolios are a formative assessment method that promotes student engagement, motivation, self-reflection and, consequently, significant learning (Marinho et al., 2021). By using portfolios, teachers can support students in the construction of their own knowledge through metacognition and self-regulation processes. This is particularly relevant in PBL approaches where the monitoring and assessment of the students' learning process is carefully planned and enhanced (S. Fernandes, Alves, et al., 2021).

This paper aims to present findings based on students' journey within a PBL experience, with particular emphasis on the development of an individual portfolio by students, as part of the assessment process. It focuses on a case study developed in the field of Education, where PBL has been implemented in the past few years (Abelha et al., 2020; Abelha & Fernandes, 2021; S. Fernandes et al., 2018; S. Fernandes, Conde, et al., 2021).

2 Context of Study

The PBL project involved three curricular units (Research Methods and Techniques II, Ethics and Education and Social and Educational Intervention Models), from the field of Education Sciences, integrated in the first year of the study plan of the Social Education degree programme at Portucalense University, Portugal. In PBL, student assessment includes several milestones where the student groups present their projects development state. These milestones aim to provide students with moments of feedback on the project development and an opportunity to clarify doubts regarding the integration of the curricular units in the project. Table 2 presents the milestones of the project, according to the last five editions of PBL projects in the Social Education degree at UPT.

Table 1. PBL-LES Project Milestones Schedule

#	Week	Milestone
1	2nd Week	Presentation of the PBL-LES Project
2	3rd Week	Open Lecture on the Project Theme
3	4th Week	Presentation # 1 (Submission in Moodle)
4	10th Week	Presentation # 2 (Submission in Moodle)
5	13th Week	Presentation # 3 (Submission in Moodle)
6	13th Week	Preliminary Project Report Submission
7	14th Week	Preliminary Project Report Feedback (for each CU)
8	15th Week	Final Presentation and Discussion of the Project (Submission of the Final Project Report)
9	15th Week	Submission of Individual Portfolio

Concerning the project's assessment components, these are distributed at different times, throughout the semester, including the following elements and weights: Presentation #1, #2 and #3 (15%), Preliminary Project Report (20%), Final Project Report (30%), Final Presentation and Project Discussion (15 %), Individual Portfolio (20%). The development of an **individual portfolio** has the purpose of enhancing student self-reflection and assessment of their work on a regular basis. The portfolio allows students to share evidence of the project journey, with particular focus on the student's learning process. Students are provided with general guidelines to develop their portfolio, but the flexible nature of this educational resource allows students to record and highlight their individual and team contributions in a very creative and personalized way.

3 Methods

This paper is based on a qualitative study which aims to give answer to the following research questions:

- How do students describe their journey during the PBL experience?
- How do individual portfolios contribute to promote self-reflection and assessment as learning?

Data analysis is based on the results of a content analysis of the qualitative data available in the individual student portfolios. For the elaboration of their portfolios, students were provided with some guiding questions, including the following: What have I learned from this curricular unit? What did I learn from participating in the PBL project? What motivated me the most in the PBL project? What difficulties have I encountered? Why? How did I get over them? What could I have done better? What did I learn about myself? What are my strengths and weaknesses? What did I learn about others? What new experiences have I done? What do I do differently now from what I have done in the past? What are my plans for the future? What goals do I have for the next semester?

Based on these topics, students based their reflections on their individual achievements, the project milestones, teamwork skills, impact of teacher feedback, celebration moments, amongst others.

4 Results

As stated previously, this paper aims to present findings based on students' journey in a PBL experience, described in an individual portfolio developed by students. The most important topics explored by students in their self-reflections are presented in the following subtopics.

4.1 What did I learn? / What skills did I develop?

When asked about what they had learned and what type of skills they had the opportunity to develop during the PBL, the students highlighted the learning outcomes that referred to the technical skills of the course units of Research Methods and Techniques I and Social and Educational Intervention Models, as can be seen in their speeches:

With the PBL project (...) I learned how to conduct questionnaire surveys, develop scripts, protocols and interviews, as well as their transcriptions (...) I learned how to carry out research projects, which should be included in the structure of a research report (...) (S6)

This project represented an area of growth for me, as it allowed me to understand how a social project should be developed, addressing the importance of each of the phases that constitute it (S5)

(...) I also learned how to conduct and transcribe an interview, something I had never done before (S10)

The PBL project was a great opportunity to acquire knowledge and enabled me to broaden my vision of the area of Social Education. (S3)

Interdisciplinarity was another aspect highlighted by students when they stated that the PBL project:

(...) was very beneficial and enriching in my learning as a Social Education student, because it allowed me (...) to apply knowledge from several areas at the same time. (S3)

(...) cross knowledge from different curricular units and take advantage of them (...) (S6)

Students mentioned that they had the opportunity to develop several transversal competencies, namely *communication skills, time management, decision-making, interpersonal skills, and teamwork skills*, as shown in the following excerpts:

(...) this project facilitated better communication as a group and a close relationship between students and teachers (S5)

One of the lessons I learnt was that developing this type of project goes far beyond communicating, it also involves collaborating, which presupposes the confrontation of ideas, the acceptance of different opinions, as well as the ability to construct joint solutions as a team. (S4)

With the PBL project, I learned to manage time better, the importance of teamwork and the allied difficulty (...). (S6)

Throughout this project, I learned to work as a team and that when you work together everything becomes easier and we can achieve a better result (...). (S10)

Today I feel more able to establish forms of communication appropriate to situations, to work in a team, to establish a relationship of trust with the other members, to build my professional identity and to present relational and helping attitudes. (S3)

(...) one of the most relevant aspects of the project was also the opportunity to develop collaborative work, which presents difficulties, but also many possibilities for growth, because with everyone's contribution, with their different ideas and critical views, the final product is certainly more enriching. (S4)

(...) allowed for a greater capacity of time management for the tasks in which it would be necessary, through this capacity of time optimisation, I was able to finish the tasks in a more profitable way (S5)

4.2 What do I now do differently from what I have done in the past?

With regard to what they consider that they now do differently from what they did in the past, as a result of the experience of the PBL project, students highlighted the greater capacity for critical reflection, reasoning, creativity, the ability to make more constructive criticisms, and the ethical care taken during the preparation and implementation of the project itself, as evidenced in the students' speeches:

(...) when comparing my pathway last year and currently, my evolution in many aspects is evident, namely today I am able to analyse more critically any procedure to be performed, as well as the reason for it. (...) (S3)

I became much more careful in the collection and processing of information, looking for suitable and reliable sources and also in the respect for copyrights and Copyright rules. (S4)

What changed most from my initial work to the final one was my ability to provide a basis, which is strongly present in the report we prepare and my capacity for creativity (...) (S5)

The way of reflecting on my own work and that of the group (...) (S6)

I learnt to make more constructive criticism on subjects which I did not know so well and which I now know more about (...) (S7)

4.3 What did I learn about myself? / What did I learn about others?

Resilience and the capacity to overcome oneself were the two aspects most often mentioned by students when they were asked to reflect on what they learned about themselves during the completion of the PBL project, as evidenced by the students' speeches:

(...) I managed to know that (...) when faced with a difficulty I do not give up and always try to find a solution. (S3)

I learned that my effort will always be rewarded and that giving up should not be an option. I also learned to value the work I do, giving my best, in a demanding context and under less than ideal conditions. (S4)

My capacity for resilience and overcoming, my level of demand, my organizational capacity and my interviewer side, eheh! (S6)

I have learned that no matter how tiring a job may be, I can find the strength and the will to do anything, that with dedication I can do anything, all I need is the will, and I have learned that I can be more committed than I had imagined. (S10)

With regard to what they consider they have learnt about others, the students' reflections focused essentially on teamwork: its implications, difficulties, added value, as can be seen in the students' discourse:

I learned that group work is not always easy. Working in a team implies communicating and collaborating, living with very different points of view and opinions, having to overcome problems together and outline solutions collectively. (S7)

Working in a team also means having the ability, by understanding the strengths and the less strong points of each member of the group, to seek to establish bridges and consensus, giving our contribution to the final product. (S4)

Regarding the others, I have learned that together we can overcome any challenge. Everyone has their own and unique characteristics, which has allowed us to have projects which are so different, but at the same time so complete. (S5)

5 Final Remarks

Assessment as learning aims to guide and provide opportunities for each student to monitor and critically reflect on their knowledge and identify the next steps. The use of the portfolio to report a student's learning process has impact on students as it provides the deepening of knowledge and reflecting on what is learned and how it is learned, besides also promoting the articulation of theory and practice (Marinho et al., 2021).

The portfolio is an assessment method that elicits students' learning and metacognitive processes. Data collected from student's self-reflections in the portfolio prove the theory about the usefulness of a portfolio, in the present case, applied in a PBL project, which allowed them to enrich the learning experience. In addition to technical aspects, they developed transversal competencies, such as communication skills, time management, decision-making, interpersonal skills, and teamwork skills which are essential in the present days. Also, the general portfolio guidelines enhanced greater creativity.

Critical reflection and ethical care are also very important achievements. As a matter of fact, when asked about what they did differently from what they have done in the past, their evolution is obvious, emphasizing their capacity for constructive criticism either about the other team members or their own performance. PBL's interdisciplinarity was considered advantageous, crossing knowledge from different curricular units.

Above all, if it would be possible to hierarchize in the present pandemic context, we would highlight the «resilience» and «capacity to overcome oneself» expressed by several students. This study induces us to conclude that the permanent contact with each other, either as a teamwork or celebration moments, including teacher's feedback related to portfolio construction, contributed to motivating and improving assessment as learning and taking responsibility for their learning and monitoring future directions.

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PBL tutoring dynamics in first-year of Industrial Engineering and Management Program

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Abstract

Project-Based Learning (PBL) methodology engages students in learning in an active practice promoting ideas discussion and share among all team members. One of the ways in which this is done is to stimulate students to solve real-world problems during a semester integrating all the Curricular Units (CU) through a large interdisciplinary project development. One of the distinguishing elements of the PBL methodology is teamwork. In this process, emerge the tutor, whose main task is to stimulate discussion and facilitate the process and direction of the students work. Also, tutor report the team progress to the PBL project coordinator. For each team a set of activities, tasks and milestones are planned in order to succeed project objectives. Taking this in line, this paper describes the tutor's role from the students' viewpoint, within the first year of the Industrial Engineering and Management degree at the University of Minho based on an online questionnaire composed by a total of 37 questions. A total of seven tutors-teachers and eight third year tutors-students were evaluated, from each group, regarding their role and their contribution to the project development. At the end of the semester, students' feedback was also collected through a focus group regarding the tutor role. Moreover, a first-person narrative of two tutors-teachers is presented. One tutor had her first experience as a tutor, the other with seven years of experience in this role. Main findings highlight a students' overall satisfaction with tutors' role and by underlining the importance of both as a team member. Nevertheless, some fewer positive points are seen as improvements opportunities for the next edition.

Keywords: Active Learning; Engineering Education; Project-based Learning; Tutor role.

1 Introduction

The learning process is an important determinant for the student learning outcomes. Currently, in a world in constant transition and evolution, teaching needs to adapt to the demands that the working world places and seeks in professionals. The learning process needs to make its transition from the traditional teaching to a more active teaching, so as to reflect this transition and embark in a teaching method that meets the learners' needs in order to develop their skills and competences. This later concept comprehends not only cognitive components but also the motivational, ethical, social, and behavioural ones, merging stable features, learning outcomes (e.g., knowledge and skills), belief value systems, habits, and other psychological features (Flumerfelt, Alves & Khalen, 2014).

According to Prince & Felder (2007), traditionally engineering has been taught deductively, which means having a lecturer presenting a topic by exposing the meaningful theory and mathematical models, demonstration and completing the cycle through the assessment of the students' ability. However, in the last few years, engineering institutions have been implementing alternative teaching methods, specifically inductive teaching ones (Graham, 2018; Prince & Felder, 2007). In inductive teaching, students are presented with a challenge, like an authentic case study, a real-world problem or a real observation. To overcome the challenge, students rapidly acknowledge the need for facts, skills, and conceptual understanding, which can happen in one of two ways: the teacher provides instruction or supports students to learn by themselves. Inductive teaching models' examples encompass inquiry-based learning, discovery-based learning, problem-based learning, project-based learning, case-based teaching, and just-in-time teaching (Prince, Felder & Brent, 2020; Prince & Felder, 2006).

In this context, lectured based classes are not enough and there is a need for more active learning methodologies, like Project Based Learning (PBL) model. PBL has been implemented in Higher Education in areas such as social education (Imaz, 2015), higher education (Guo, Saab, Post & Admiraal, 2020), health

(Demirören, Turan, & Teker, 2020; Edelbring, Alehagen, Mörelius, Johansson, & Rytterström, 2020; Khamchiyev, Batyayeva, Shandaulov, Zhashkeyeva, Suleimenova & Sagimova, 2020), e-learning (Amamou & Cheniti-Belcadhi, 2018), computer engineering and software development (Cornejo-Aparicio, Flores-Silva, Bedregal-Alpaca & Tupacyupanqui-Jaen, 2019), STEM (Prince, Felder & Brent, 2020) and engineering (Beneroso & Robinson, 2022; Kuppuswamy & Mhakure, 2020; Rivaldi, Megayanti & Aryanti, 2020).

PBL is sustained by a project brief around which students perform a series of tasks guiding to the delivery of a final product that can be: a design, a device, a model, or a computer simulation (Guo, Saab, Post & Admiraal, 2020). Therefore, PBL engages students in active learning, promoting ideas discussion and sharing amongst all team members. Throughout a semester, students are motivated to solve authentic, real-world problems through a large interdisciplinary project development and integrating all the Curricular Units (CU). Teams are formed and for each team a set of activities, tasks and milestones are planned. Each team tackles the project, providing a solution and delivering in the deadline the product developed, as a prototype and a team-report (Powell, 2004). The students will develop skills such as team work, leadership, ability to listen, participate actively, collaboration, cooperation, respect other's views, ability to critically analyse and evaluate literature, focused study and use of resources, and mastery of presentation skills.

In this methodology, teamwork tutors are a distinguishing element, having as role stimulating discussion, facilitating the process and reporting the team's progress to the project coordinator, among others (Alves, Moreira & Sousa, 2007; Alves, Moreira & Sousa, 2010). By asking the right questions, the tutor will lead the student in learning, setting appropriate learning objectives and providing feedback on his/her learning. Hence, PBL demands a mind shift in teachers, transferring in students' hands their own learning responsibility.

This tutelage can be done by teachers included or not in the CU of the semester, researchers or upper classes students (Simão, Flores, Fernandes, & Figueira, 2015). Few are the studies reporting on the tutor's role performed by students (Abbot, Graf & Chatfield, 2018; Alves, Moreira, Leão & Teixeira, 2017). The literature reported one more case of PBL in an engineering-design course which presented a sort of peer tutoring through what it was called "peer interactions", but in a much more informal basis (Kuppuswamy & Mhakure, 2020). In Alves, Moreira, Leão & Teixeira (2017), each PBL team has two tutors: one teacher and one third year student.

In this paper, the tutor's role from the students' viewpoint is described, within the first year of the Industrial Engineering and Management (IEM11) degree at the University of Minho. It is based on an online questionnaire composed by a total of 37 questions to the students that went through the PBL. Towards the semester's end, students' feedback was also collected by means of a focus group concerning the tutor's role. Furthermore, a first-person narrative of two tutors-teachers is highlighted. One tutor had her first experience in this role, the other has seven years of experience.

This paper is organized in five sections. This section introduces the objectives of the paper followed by a brief literature review regarding the tutor's role in PBL. Then, the research methodology and the tools used to collect data are presented. The main results found are presented and discussed. Ending the paper with the final remarks.

2 PBL: brief description

This section describes the context of PBL in engineering and the corresponding role played by the tutor, particularly at the first year of the Industrial Engineering and Management program at University of Minho.

2.1 PBL in engineering

PBL model has been implemented at University of Minho since 2004_05, at the Industrial Engineering and Management Master Integrated program of the first year, first semester. Since then, PBL has been improved through continuous action-research-practice cycle, engaging all stakeholders, from students (Alves & Leão, 2015; Fernandes, Mesquita, Flores, & Lima, 2014) to researchers and teachers (Alves, Sousa, Fernandes, Cardoso, Carvalho, Figueiredo & Pereira, 2016). PBL engages students in active learning, emphasizing ideas

discussion and sharing amongst team members. The students are motivated to solve authentic, real-world problems during a semester, integrating all the CU through a large interdisciplinary project development.

Within PBL methodology, teamwork tutors have to be emphasized by their important role: making questions; stimulating discussion; facilitating the process; motivating the teams and reporting to project coordinator the team's progress. The tutor should, as well, keep the team focused on the set of activities, tasks and milestones established to achieve project objectives.

In 2016_17 academic year, the tutor's role, which until then had been exclusively performed by teachers, was also voluntarily assumed by third-year students (Alves, Moreira, Leão & Teixeira, 2017). These authors, investigated the tutor's role from two perspectives: 1) the tutored students and 2) the tutors. Additionally, the differences between the tutored perspectives from tutors-students and tutors-teachers were also analysed. The teams perceived the tutors-students as "godfathers" and as someone who has carried out similar experience and difficulties. Therefore, this paper introduces the concept of peer tutors as a novelty, being carried out by third-year students from the same program.

Falchikov (2001) identified four peer tutoring types in higher education: 1) students tutoring other students in the same level and class; 2) students tutoring other students in the same class, but with a special status specified by the course instructor; 3) students tutoring other students in the same institution, but at a different level; and 4) students tutoring students at different levels and from different institutions. The peer tutoring type described in Alves, Moreira, Leão & Teixeira (2017) is the "students tutoring other students in the same institution, but at a different level".

Interestingly, Abbot, Graf & Chatfield (2018) studied the same peer tutoring type through a case study. Within the peer tutors' understanding and satisfaction with their tutoring experiences, the authors identified the importance of three aspects: the professor-student relationship; role clarity and expectations, and tutor positionality (tutors navigate between students and instructors). They concluded that tutors would support the students better, enjoy the tutoring experience and feel connected to the course's purpose, when all the stakeholders involved (tutors, students and professors) have the perfect notion of the tutor's role. Additionally, they emphasized that the peer tutors perceived themselves as liaisons, intermediaries, and connectors, bridging the world of professor and student.

Kuppuswamy & Mhakure (2020) presented the use of PBL in an engineering-design course, offering students the opportunity to experience engineering design like the way how it was practiced in real industry context. The students were supported through formal and informal lecturer's consultations, workshop activities and through "peer interactions" - where students use the other student's thinking as resources, as a kind of peer tutoring, but on an informal basis. Also, Rivaldi, Megayanti & Aryanti (2020) investigated the digital peer tutoring in engineering education, particularly in engineering drawing subjects. According to them, with peer tutoring, students felt more supported when they were ashamed to ask the tutor about some difficulties or even some non-understanding, because their peers translated knowledge in their language, and simultaneously the tutors felt helped.

2.2 Tutor Role

In PBL, the tutor's role is essentially related with following the progress of a student's team and the associated activities leading to the suitable project development. The tutor will monitor the team activity, regarding conflicts amongst teammates and other subjects, will apply a set of activities related to project management, like the ones associated to project planning, to tasks' division and allocation, meetings realization, and so on, in order to accomplish the project objectives. The tutor likewise reports on the teams' progress to the coordinating team and offers a complementary perception on the team members' work behaviour relatively to the ones of the CU lecturers.

In this context, team success on accomplishing the project to be developed, depends on the tutor's persistent and paced activity, ensuring the project progress within safe limits and recording decisions and progress made (Cornejo-Aparicio et al., 2019; Grunefeld & Silén, 2000). The tutor is a facilitator (Demirören, Turan & Teker, 2020) and should enable a fluid process of project management, as stated by Powell (2004). According to him,

the tutor should propose strategies, helping the team to generate ideas and identify important points to follow and guiding efforts in order to progress the work and triggers its development, instead of contributing with answers and solutions. Thus, attributes for tutors like being a good listener, making the right questions and guiding the efforts look to be important attributes.

The tutor making the right questions, in PBL, will guide the students to search for knowledge and thus allowing them to fully engage in the construction of their knowledge, as they are the focus of the learning activity (Demirören, Turan & Teker, 2020; Imaz, 2015). This construction will be done through several sources, such as the CU lecturers' support, which should be consulted as learning resources during the PBL process deployment. As well the tutor will support similarly, but his/her main goal is to make the right questions to the team, being this much more important than give answers, because it will trigger the creative process of the team. The tutors should guide the team towards the CU lecturers and also to external entities, whereas the lecturers will provide technical guidance and knowledge. Thus, according to Amamou and Cheniti-Belcadhi (2018), the tutor will act as a mediator among the students and the objects of knowledge which represent the knowledge to achieve.

In PBL, maintaining a suitable motivation throughout the project is the team's most significant challenge (Demirören, Turan & Teker, 2020), because a number of difficulties might happen in some project phases, leading to disappointment and to frustration. Thus, throughout the project, and in order to guaranteeing a uniform motivation of the team, one of the tutors' challenges is to support the team (Alves, Moreira & Sousa, 2007). These authors presented as well the students' perceptions concerning the practice of the tutor's role at the interdisciplinary IEM1 PBL at the University of Minho: a) availability (to meet with team); b) contribution to solve conflicts amongst team members; c) facilitating debate within the team; motivation and trust on the work carried out by the team; e) providing directions for pursuing the project tasks. Later on, Alves, Moreira & Sousa (2010) researched the similarities and dissimilarities of the tutor's experience between different years of the IEM curricula. The findings demonstrated that in PBL of advanced academic years, the teams have a tendency to be more autonomous and have a broader confidence on their solutions. Furthermore, conflicts on the teams look to be less challenging. They also reported that tutors appear to perform differently between their peers, which appear to be related to each individual distinctiveness.

According to Weenk, Govers & Vlas (2004) attending that the tutor's role is not straightforward to achieve, the tutor should have previous training on tutoring teams, specifically regarding competencies' development on problem solving and conflict management, whereas guaranteeing that the process learning within the team is done on a cooperative basis. The authors also suggest as a main aspect on tutor's role that his/her job is not to offer technical solutions nor direct the project, but instead encourage students to learn, think and solve problem by themselves, in order to stimulate their autonomy.

3 Research Methodology

This section describes the sample and the methodology followed to gather data to fulfil the main objective obtained from: (i) students' questionnaire, (ii) focus group; and (iii) tutors-teacher first person narrative.

Based on tutored students' answers, the main research paper questions focused on this study are:

- What are the relevant tutors' attitudes in the context of PBL?
- Do teachers and students play tutors' role in the same way?

The data collected was analysed by non-parametric test (Mann-Whitney, U, for the comparison of two independent samples means) since they do not follow normality (normality verified by Shapiro-Wilk test). The statistical software SPSS 28.0 was used for the analysis.

3.1 Sample Characterization

The majority of enrolled students (approximately 65%) voluntarily participated and fulfilled the questionnaire, 83% was of female gender, and at least one student of each team fulfilled the questionnaire.

3.2 Questionnaire description

The questionnaire used in this study "Learning by project: tutor's assessment" was developed and validated in previous study using the population for which it has been developed and validated (Alves, Moreira, Leão & Teixeira, 2017). Succinctly, the questionnaire has 37 questions, separated in ten sections according to the topic in evaluation: 34 closed questions on a 5-levels Likert scale base (1-totally disagree to 5- totally agree), two open questions and final general question in a 10-levels of agreement. The "not applicable" option was also considered, upholding specific situations where the topic in evaluation was not applicable to tutors-students. Each student, voluntarily, fulfilled a questionnaire for each tutor in their group. In Table 1 the most applicable questions used to answer the research questions are listed.

3.3 Focus group

The focus group that occurred at the end of the semester, allowed to gather students' feedback regarding the PBL functioning. The present students, divided into five focus groups, apart from the tutor role, discussed also other topics too, namely: peer assessment, CU integration in PBL project, project networking, teachers' support and feedback, and final marks. All these topics were discussed for four hours following the presentation of the summary of how the semester run, in a nice and informal environment.

3.4 First person narratives

First person narratives of two tutors-teachers are presented: one tutor had her first experience as a tutor (identified as Tutor1), the other has seven years of experience (Tutor2). These narratives describe perceptions regarding PBL knowledge and motivation to be a tutor-teacher, difficulties felt and attitudes to overcome them, and general opinion. Another worth mention aspect is that these two tutors are two of the authors of this paper.

4 Results and Discussion

This section depicts the results of the study based on the quantitative analysis of the students' answers and student' focus group regarding the tutor's attitudes and role, and tutors-teacher first person narrative of their experience as tutor.

4.1 Tutors' attitudes and role: Questionnaire analysis

The data collected was analysed by non-parametric test Mann-Whitney, U, for the comparison of students' perceptions regarding the two tutors' (teacher and student) attitude and role.

Table 1 presents the corresponding statistics in terms of mean and standard deviation, minimum, maximum, and median values obtained according to the questions defined for the quantitative analysis. On average, and regarding the topics under study, students demonstrated to be in agreement for both students (T-S) and teachers (T-T) tutors (mean values around 4 and median values equal 5 in most questions).

However, in three topics, the difference in agreement is statistically significant (based on the obtained p -value, where the lower the p -value, the greater the statistical significance of the observed difference), showing a different tendency on how students see teachers and students tutors' role, i.e.:

26. "the tutor discussed with the team the results of peer assessment, of the team and auto-peer assessment" ($p < 0.005$), where tutors-teachers is rated highest at median 5, with mean 4.64 close to "totally agree" (Figure 1.a);

27. "the tutor emphasized the importance to create internal mechanisms that support the team working operation" ($p < 0.05$), where students evaluate more positively the tutor-student at median 5, with mean 4.63 close to "totally agree" (Figure 1.b);

17. "the tutor supported the team in the accomplishment of the objectives" ($p < 0.06$), nevertheless students evaluate both students and teachers with the same median (5), tutors-students presents a higher mean (4.63).

Table 1. Questions used in the quantitative study and relevant statistics.

Section	Questions	n_{T-S} = 34	n_{T-T} = 32	n_{T-S} = 34	n_{T-T} = 32	n_{T-S} = 34	n_{T-T} = 32	Statistic U
		mean \pm s.d.		min; max		median		
III. Attitudes	The tutor...							
	4. communicated clearly	4.74 \pm .51	4.69 \pm .74	3; 5	2; 5	5	5	527.5
	5. showed enthusiasm in the performance of his/her role	4.38 \pm 1.2	4.38 \pm .94	1; 5	2; 5	5	5	469.5
	8. was prepared for the meetings	4.26 \pm .93	4.41 \pm .72	1; 5	3; 5	4	5	465.0
	9. supported, instead, of lecturing	4.44 \pm .76	4.65 \pm .66	3; 5	3; 5	5	5	422.0
	10. stimulated a safety environment where the students feel they are will to express their ideas	4.84 \pm .52	4.68 \pm .70	3; 5	2; 5	5	5	433.5
IV. Project monitoring	The tutor...							
	11. put challenges and relevant questions	4.16 \pm 1.1	4.39 \pm .76	3; 5	2; 5	4.5	5	464.5
	13. stimulated the team thinking in different points of view	4.33 \pm 1.1	4.65 \pm .71	1; 5	2; 5	5	5	434
	16. provided feedback when necessary/solicited	4.59 \pm .84	4.77 \pm .50	2; 5	3; 5	5	5	471.5
	17. supported the team in the accomplishment of the objectives	4.63 \pm .87	4.31 \pm .97	2; 5	2; 5	5	5	396.0 *
	18. stimulated the team members to an active participation	4.44 \pm .96	4.34 \pm 1.0	1; 5	2; 5	5	5	514.5
	20. helped the team to distinguish the essential from the accessories	4.55 \pm 1.1	4.39 \pm .96	1; 5	2; 5	5	5	442.0
V. The critical thinking development and problem-solving	The tutor...							
	22. encouraged the team to critically analyse the information	4.29 \pm 1.0	4.59 \pm .68	1; 5	3; 5	5	5	390.0
	23. emphasized that all members of the team are responsible by the process and project final result	4.59 \pm .71	4.53 \pm .80	2; 5	2; 5	5	5	503.0
	24. stimulated the autonomy development of the students	4.63 \pm .72	4.45 \pm .85	3; 5	2; 5	5	5	411.0
VI. Teamwork function	The tutor...							
	26. discussed with the team the results of peer assessment, of the team and auto-peer assessment	3.62 \pm 1.4	4.64 \pm .87	1; 5	1; 5	4	5	202.0 ‡
	27. emphasized the importance to create internal mechanisms that support the team working operation	4.63 \pm .75	4.21 \pm .94	2; 5	2; 5	5	4	338.5 **
	29. tried to orient the team when they feel lost	4.53 \pm .90	4.28 \pm .92	1; 5	2; 5	5	4	348.0
	31. had an active role in the dynamism of the team	4.09 \pm 1.0	4.06 \pm 1.1	1; 5	1; 5	4	4	496.0
VII. Individual learning	The tutor...							
	33. insisted in an equal division and task turnover in order to all members develop project competences	4.24 \pm 1.0	4.03 \pm 1.1	1; 5	2; 5	5	4	454.5
X. General	How you classified, in general, the tutor performance?	8.54 \pm 2.4	8.42 \pm 1.9	2; 10	3; 10	10	9	484.0

‡ statistical significant differences for $p < 0.005$; ** statistical significant differences for $p < 0.05$; * statistical significant differences for $p < 0.06$; s.d. standard deviation; T-S Tutor-Student; T-T Tutor-Teacher

It is worth to emphasize that questions 26 and 27 are concerning the teamwork function and question 17 to the project monitoring. The last two results to questions 27 and 17, could refers that students-students present more facility in dialogue than students-teacher, as if they speak the "same language".

Concerning the attitudes, students assess positively both students and teachers' tutors (median 5, with the exception of 4 for tutors-students in question 8). That means that the communication between students and tutors is clear, showing enthusiasm in the performance of his/her role, demonstrating an early preparation of the meetings, stimulated a friendly but focused environment where students feel they are will to express their ideas, and that a tutor supported, instead, of lecturing. This last topic is very important issue being in accordance to Amamou and Cheniti-Belcadhi (2018).

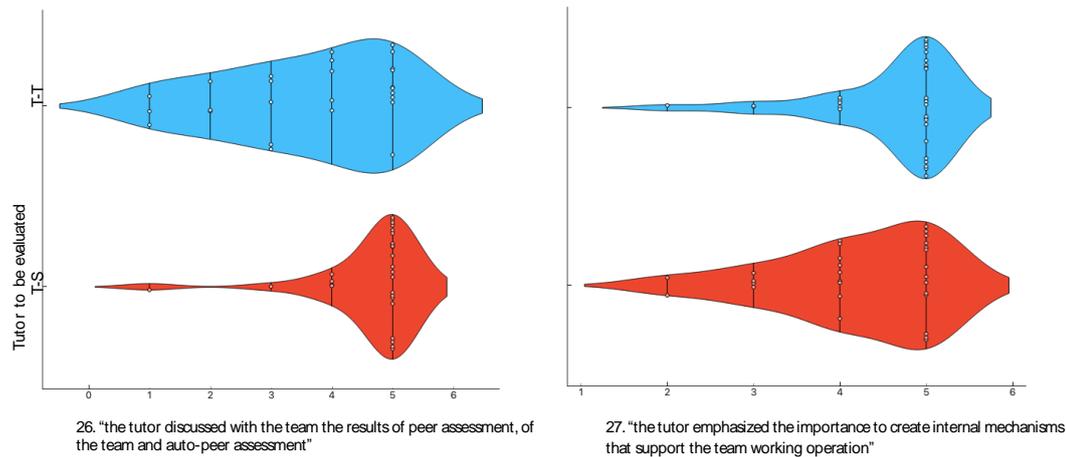


Figure 1. Students' answers distribution for question 26 (a) and 27 (b) for both tutor-student (T-S) and tutor-teacher (T-T).

Also, the results show how students positively perceive the tutors role regarding critical thinking development and problem-solving and the importance that this has in continuously motivate the team (Demirören, Turan & Teker, 2020; Alves, Moreira & Sousa, 2007).

4.2 Focus group

The students present in the closure PBL semester meeting were divided into five focus group, discussed the tutor role among other topics, as previously mentioned. The following are particular points of focus in respect of providing the general opinion of students related to tutor role in PBL project development.

Students presented distinct opinions regarding the tutor role, sustaining the answers given in the questionnaires as previously analysed.

The negative opinions are regarding the less positive experience with the tutor. For example, the absence of one tutor (particularly the tutor-student) throughout the semester. Nevertheless, broadly and unanimously students agree on the importance of the tutor presence and role in a PBL project development.

In PBL project, tutor concept encompasses the binomial teacher and third-year student.

4.3 First person narratives

Tutor1, as her first experience as a tutor-teacher, refers that this was a very interesting and challenging one:

"My first contact with PBL was as a teaching professor in a CU, on a previous PBL edition."

Her knowledge about PBL ranged from this later experience to conversations with the other counterparts regarding PBL purpose and functioning. Another challenge embraced was tutoring two teams.

By contrast, Tutor2, besides the experience in recent years as tutor of a PBL team, is a teacher from different engineering area than the Industrial Engineering and Management. This is a challenging and motivating experience, where the creation of new ideas and to work with freshman students are the reason.

Both agree and identify the difficulty inherent to the first contact. Students show some shyness and felt lost, not knowing what to do and what is expected to do in a PBL project. It was interesting to acknowledge that the students' perception about the tutor's role was somewhat far from what is a PBL tutor role. As tutor, the first task is to define the tutor meaning in a PBL project, as students thought that tutor would present them with solutions and decide the way forward in the project:

"... first, I (Tutor1) began by reading the project's guide with them, particularly the tutor's role, the project description (theme, project context, project objectives) and skills to acquire. Then, I reinforce that a PBL tutor must be a facilitator, an expert using his/her knowledge mindfully within the project context, a mentor, a team builder who is there to guide the team for the project solution and, that is someone they can turn to, in case of doubts, problems and would help in conflicts, if they occur."

After beginning the PBL project, to support the team, weekly meetings were planned. Accordingly, the students' behaviour, tutors-teacher adjusted their approach and take action. For example, make questions in order to understand students' rationale thinking process and to identify the type of research done. Consequently, suggestions about knowledge supports and database they should delve into. Based on Tutor2 experience, this questioning process happen or not, in line with the students' autonomy level. Eventually, the students make a lot of questions, and discussions in order to drive their path within the project solution, when they were more comfortable with the PBL project, creating group dynamics and trust between all members.

Tutor1, after this experience, identified some improvement points, namely: scheduling some kind of extra-curricular activity or some informal event, outside the project room environment, to get to know each other and to create bonds between all the team members. Regarding this extra-curricular activity, Tutor2 mentioned that had opposite experiences: one, where all together went for an informal tea/coffee break at the end of the semester, and another where the semester ended in a normal way.

Tutor1 refers that the PBL tutor role is an opportunity to work closely with students, observing their behaviour, shaping their learning in real-time and within the dynamic setting of the project room. Both tutor-teachers agree that:

"... it is an experience to be repeated."

5 Conclusion

This study presents the main results in order to analyse how PBL students perceived the tutors' role. Thus, to fulfilled this objective two research questions were defined: "What are the relevant tutors' attitudes in the context of PBL?", and "Do teachers and students play tutors' role in the same way?". The data were obtained in three different ways: a students' questionnaire, a focus group and a tutors-teacher first person narrative of their experience as tutor.

Generally speaking, students perceived positively the tutors' role in the PBL project development where communication has a large part to play in this process. For this reason, students see the tutor-student more near them as a partner, and the tutor-teacher as the more-experienced partner. Additionally, tutors are recognized as a key element, essentially in a first year of a programme, due to the inexperience of students in a new environment and learning process. However, tutors, students or teachers, performance is always dependent on the skills and motivation of the tutor to assume this role. Maybe, as future work, a kind of interview could be made to tutors to realize about their intrinsic motivation and select them based on this interview.

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PBL to design a Gamified Financial Management Application for the socially vulnerable

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Abstract

This paper presents the prototype of "MobEdu": a gamified app that responds to the need for financial management training, for a community in state of vulnerability in Brazil, with low schooling and semi-literacy, by using engagement strategies. This work was developed in partnership with five different courses conducted via Problem-Based Learning (PBL) methodology, in the Industrial Engineering course of the University of Brasília. The results presented here were obtained by students of the Production Systems Project 2 (PSP2) course, who developed exploratory research, with a qualitative approach, using FIGMA as a prototype design tool. The steps of the research were: requirements elicitation, development of a system vision document, user flow mapping and use case diagrams, and finally a prototype interface. Gamification strategies can be key elements to engage people to use an app, and this proposal was developed to promote a high engagement of the vulnerable community in a financial management application.

Keywords: Mobile Learning, Gamification, Financial Education, Interface Development, Interdisciplinary Project.

1 Introduction

In January 2018, the largest dumpsite in Latin America shut down its activities, submitting more than 1,800 waste pickers to a compensatory monthly salary payment flow of garbage cooperatives. The waste pickers community was working autonomously before, and now they have been subjected to this new mode of payment, without prior knowledge of basic financial management. In this context, researchers of the University of Brasília identified an opportunity to develop a financial management tool, aimed at communities in a state of vulnerability, with low education and semi-illiterates.

According to Vieira, Moreira Junior and Potrich (2019), Brazil's financial education is being highlighted due to the *Estratégia Nacional de Educação Financeira (ENEF)*, a national strategy that promotes financial education and social security, contributing to the strengthening of citizenship and conscious decision-making by costumers (BRASIL, 2010), developed by the Central Bank of Brazil. This was brought to practice together with another trend in education: gamification. It can be done via a strategy to make people and their organizations interact with background content and information needed for decision-making, by playing a ludic game that makes learning a challenging and funny experience (FADEL, 2014).

In addition to the development of the tool's interface, it has been noticed that challenge-based gamification improves the outcome of learning (Legaki, 2020), therefore, the format of engagement became as essential as the user interface. As a result, the application was incremented with a gamified journey, aiming at the greater engagement of the target audience in the usage of the tool's features.

This paper focuses on the results of the Production System Project 2 (PSP2) course, which has delivered a prototype of an app, and it is presented in four topics: i) theoretical references, with a theoretical basis; ii) methodology used to create the application, which unifies mobile education, financial education, and gamification; iii) results and iv) conclusions.

2 Theoretical References

A literature review was conducted to show an overview of the subject matter, and to understand the state of the art and how it could relate to the objective of this research.

This project was developed in the context of the New Epic - SDG Challenge⁸, a program that takes place every year, coordinated by a group of professors and students from the University of Aalborg, Denmark, and the University of Brasilia, Brazil. According to the UN (United Nations), the SDGs (Sustainable Development Goals) are the main focus of the 2030 Agenda, united into 17 goals, each goal represents main activities that should be considered for the achievement of the 2030 Agenda's purpose: guarantee human development and the basic needs of the citizen of the whole world through an economic, political and social process that respects the environment and sustainability in the present and the future. The projects were developed in accordance with one of those goals.

This paper presents the project "Mobile Education," related to target 2 of SDG 10 – Reduced Inequalities - "By 2030, empower and promote the social, economic and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or another status". To promote empowerment and social and economic inclusion, it is necessary to teach waste pickers how to manage their money correctly.

This project was developed in the realm of interdisciplinary projects. Interdisciplinary can be understood as the crossing of existing disciplines resulting in a new one, especially in the scientific courses in the organizational and the industrial subject fields. This is the case of Operational Research, which is an operational investigation area that came across out of the fusion among scientists, engineers, and the military (Pombo, 2008). Interdisciplinary projects are the result of the fusion of project ideas that float around in different areas, that when brought together to develop a solution, can be mutually beneficial in finding methods and tools to achieve their goals. Interdisciplinary projects are a trend in modern education and university courses are being designed to meet this goal: to bring students and professors of different knowledge areas or courses working together, in learning by doing manner. The work in an environment that is project-based education and solution-driven initiatives, with cooperation in many different levels (EVANGELISTA; COLARES; FERREIRA, 2009).

Bayuk (2019) presents how smartphone apps can aid in the financial health of their end-users. The study was conducted in an interdisciplinary manner, by exposing the group under review to game apps about finance that has social tools, such as abilities to share achievements, or economic tools, such as the ability to earn real money. The study found that consumers vary in their preferences for certain features based on their previous experiences with other financial management apps, with those who had prior contact tending to exhibit greater subjective knowledge and engage more with "social" and "economic" features of financial apps, while those with no experience are more motivated by economic features.

Vieira, Bataglia and Sereia (2011) define financial education as measures that aim to create and transmit financial information to individuals, by providing them the ability to distinguish the advantages and risks of their choices. Moraes (2019) explains that the main objective of financial education is to instruct people on how to manage their monetary resources, by helping them make conscious decisions that enable them to save and invest, and ensuring that they live well financially, whether in the present or the future.

According to Legaki et al. (2020), challenge-based gamification improves learning outcomes. As a result, it showed that the performance of their study audience was improved by 34% through gamified education and that better results can be acquired through gamification combined with traditional study methods such as reading. However, any interaction with a gamified application, in a lecture, for example, can already be considered beneficial to students. Peixoto et al. (2015) present in his study a systematic mapping of the use of gamification in educational software in the context of Brazilian research and concluded that only thirteen Brazilian institutions conduct studies in the field of gamification for education, and the software most used are web-based systems.

3 Methods used

This paper is an outcome of a project developed under the Mega-theme "Mobile Education" of the SDG Challenge. It involved five different courses from Production Engineering PSPs courses (i.e., Production Systems

⁸ The mission of the SDG-Challenge is to connect and mobilize students and organisations to work together on the Sustainable Development Goals (SDGs) of the United Nations (UN). These goals are set to combat climate change and to reduce the inequalities in the world. [New EPIC + SDG Challenge 2020. https://www.sdgchallenge.com.br/](https://www.sdgchallenge.com.br/)

Projects) of the University of Brasilia (UnB): Production Systems Project 1, 2, 3, 5 and 8 (PSP1, PSP2, PSP3, PSP5 and PSP8), in an interdisciplinary manner. PSP1 carried out the data collection via interviews, thus supporting the Production System Project 2 (PSP2) course in the requirements elicitation with stakeholders. PSP2 students were responsible for the design of a prototype interface. PSP3 teams created the educational content that is displayed in the application. PSP5 teams worked on the quality control of the prototype developed by PSP2, and the PSP8 team managed the integration of the project portfolio, all those five courses were managed by using PBL (Problem Based Learning) as a learning methodology.

The app's interface was developed with a focus on a challenge-based gamification journey, to engage and motivate the target users of the platform, based on the DML (Dynamic Model for Gamification in Learning), presented by Peixoto and Silva (2015) and Kim (2013).

The focus of this research was the PSP2 course, responsible for the development of the app prototype named "MobEdu". An applied research was carried out, with a qualitative approach, and the techniques used for data collection were based on querying an indexed database for requirements elicitation, in addition to the input provided by the PSP1 course.

The research methodology was structured in 5 phases: (i) Development of a system vision document, (ii) Requirements Elicitation, (iii) User Flow Mapping, (iv) Use Case Diagrams and (v) Prototype Interface.

4 Research Results

4.1 System Vision Document

A vision document was written by the PSP2 group in order to provide a high-level system view and more detailed technical requirements of the application, such as scope and non-scope, app building team, functional and non-functional requirements (represented visually in Figure 2), constraints, and a primary interface prototype.

The vision document was essential to present to the stakeholders (professors and students) the steps taken to elicit the functional and non-functional requirements via user's needs and a literature review, to meet the expectations, to adapt them to stakeholders' suggestions, such as in the application's boundaries and the interfaces, to build the application's prototype.

4.2 Requirements Elicitation

The system requirements specification was divided in two parts, based on Pressman (2009): the functional requirements, which refer to all the features that the application must present, described in Table 1, and the non-functional requirements, which refer to the services and restrictions presented by the system, described in Table 2.

Table 1. System Functional requirements list.

N°	Name	Functional Requirements Description.
RF001	Register and log in	It allows performing user registration by storing information, user and password.
RF002	User Validation	It allows to view and validate information about application users.
RF003	Change User	It allows to view, change and delete information about application users.
RF004	Create Avatar	It allows the creation a user's avatar.
RF005	Edit Avatar	It allows to view and edits the user's avatar
RF006	Store Avatar	It allows the storage and view of accessories purchased with fictional coins.
RF007	Control fictional coins.	It allows to record and view historical earnings and spending of fictional coins.
RF008	Include Courses	It allows you to insert courses into the app.
RF009	Keep Courses	It allows changing existing courses in the app, as well as recording and viewing completed courses.
RF010	Exclude Courses	It allows deleting existing courses in the app.
RF011	Integrate family users	It allows to create, change and delete a family group.

RF012	Integrate work users	It allows to create, change and delete workgroups.
RF013	Keep financial control	It allows to record, change, view and delete financial data.
RF014	Share link	It allows sharing the application link with a certain personalized identifier for each user so that you benefit only.
RF015	User Guide	It allows solving app usability questions.
RF016	Control Notifications	It allows controlling notifications for everyday alerts and fosters user engagement

Table 2. Non-functional requirements list.

N°	Name	Non-functional Requirements Description
RNF001	Usability	The system must make it easy for the user to understand the functionality available by using symbols. It should have a simple presentation making the execution of actions intuitive and logical.
RNF002	Performance	The system must have a maximum response time of 3 seconds.
RNF003	Storage	The system must be able to store data both locally and in the cloud.
RNF004	Security	The system must be able to register a password per user.
RNF005	Compatibility	Must be compatible with Android 6.0 or higher operational systems.
RNF006	Legality	The system must comply with the General Data Protection Law (LGPD) as well as restrictions for an application by entering the terms of use, terms of the customer.

4.3 User Flow Mapping

The user flow mapping shows the main features that users need order to use the app. It was built according to the system requirements specifications and shows the required user journey in order to achieve the functions related to the financial education goals.

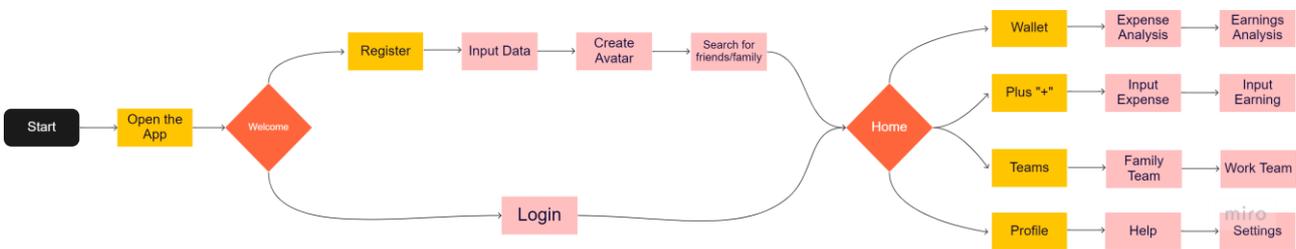


Figure 1. User Flow Map

Initially, the user opens the application, to log in or to create a new account. Then user must enter their main data, create their avatar and search through their contact list to find other users in the app. Then the user is directed to Home page of the application, and has the view of four main icons on the dashbar: Wallet, Plus, Teams and Profile. In addition, the user can also navigate through the homepage and access other relevant information such as: courses, medals, coins, etc

4.4 Use-case Diagram

The use case diagram, shown in Figure 2, was designed out the list of the functional requirements, presented in section 3.2, and by analysing the business model.

The use-case diagram represents the interaction between the user and the system administrator, and their main assignments within the application.

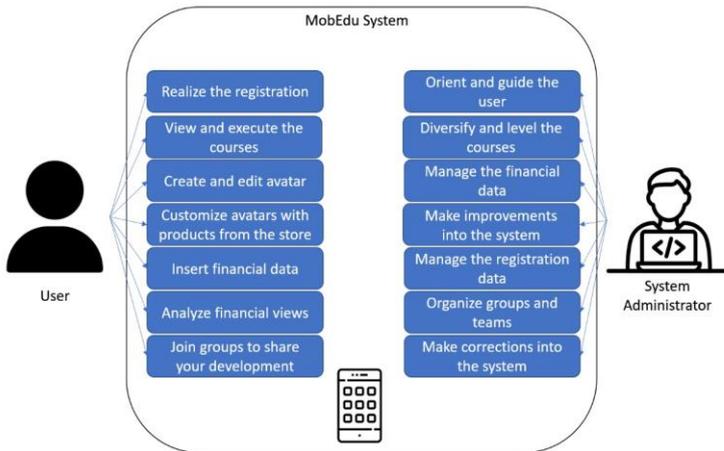


Figure 2. Use-case diagram.

4.5 Prototype Interface

The application was created to help waste pickers to take better care of their finances. The scenarios presented in the application's prototype bring features and elements designed exclusively to better meet the needs of those users, in total, 69 interfaces were created, however, only 22 will be presented below.

The designing and prototyping of the application, throughout the research, were created by using the following tools: "Figma" - used to effectively design the screens and visualize them as a functional application; "Power BI" - Used for testing the application's points and data entry system by displaying reports; "Adobe Illustrator" - Used for designing the application-specific content; and "Miro" - used for the collaborative work of the prototype development team, of a flowchart of the app's screens.

4.5.1 Registration and Login

The Welcome screen was built to guide the user during the registration process in the application and to collect key data, such as name, phone number, and identification number. After registering, it is possible to accept the option to find friends and family who use the application. The user can also choose to indicate friends and family by sending a link, from the moment the link is used, the main user obtains their first virtual coins. On the Login screen, the user should fill in their identification number and password to enter the account. In the case of forgetting the password, the user should choose the "forgot my password" button, receiving a confirmation code by message to set a new password.

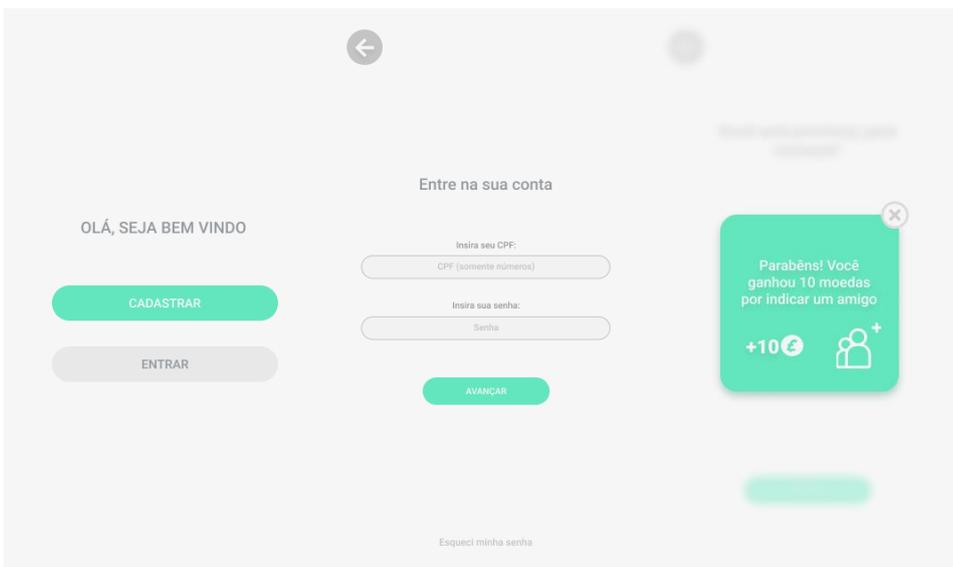


Figure 3.a Welcome, 3.b Login, 3.c Reward Pop-up

4.5.2 Creating an Avatar

In Figure 4, the user can create their avatar by choosing the skin tone, hairstyle and clothing pieces for the top and bottom parts. When creating the avatar, the user is rewarded with virtual coins to spend on accessories in the app store.



Figure 4.a Avatar creation, 4.b Avatar creation, 4.b Store, 4.c Reward Pop-up

4.5.3 Home page features

Figure 5. a presents the home screen, the screen offers the user an overview of the main information available in the app, it presents monthly earnings and expenses, progress in the financial education courses, earned coins (Figure 6.a), courses (Figure 6.b), medals (Figure 6.c) and store (Figure 4.c). Figure 5.b, presents the navigation bar, where the user can navigate through other screens, such as the wallet (Figure 8.a), the team's screen (Figure 9.a), and the profile configuration screen (Figure 7.a).

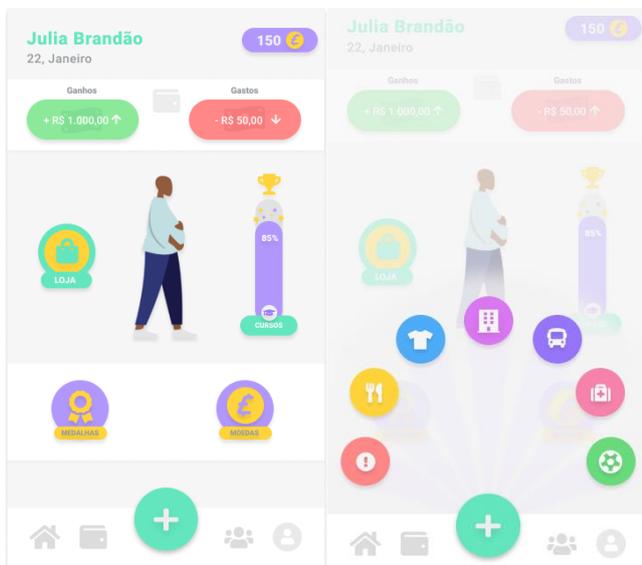


Figure 5.a Home, 5.b Overview

4.5.4 Courses and Medals

Figure 6.a presents how the coins were obtained, after the registration, virtual coins can be obtained through three steps: by indication, by adding data to the earnings or expenses report, or by watching the available courses in the app. Figure 6.b presents the courses screen, where the user can access the financial education content of the application. Figure 6.c presents the medals earned by finished courses, the user also has the

option to share the medal via WhatsApp (Figure 6.d), medals with a lock symbol can be obtained by completing the equivalent course.

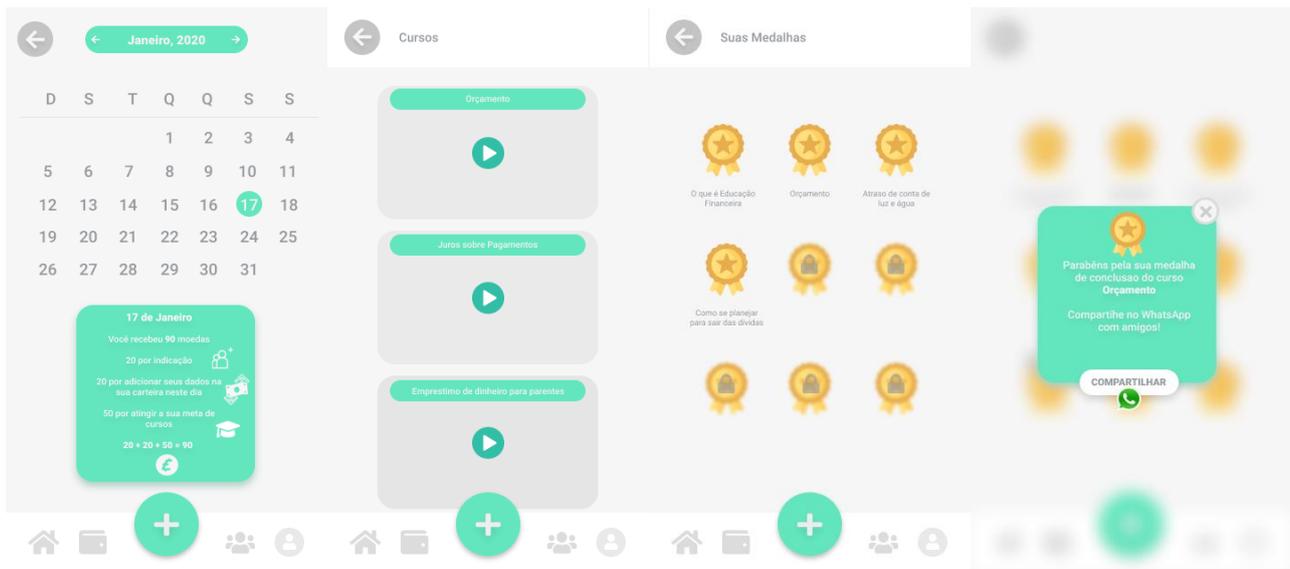


Figure 6.a Calendar, 6.b Courses, 6.c Medals Overview, 6.d Share your Medal

4.5.5 User's profile features

Figure 7.a presents the registered user information. Figure 7.b presents frequently asked questions and instructions for the app usage. Figure 7.c presents the settings option of the app: privacy, notifications, change password, invite code, search contacts, term of the user and deactivate the account.

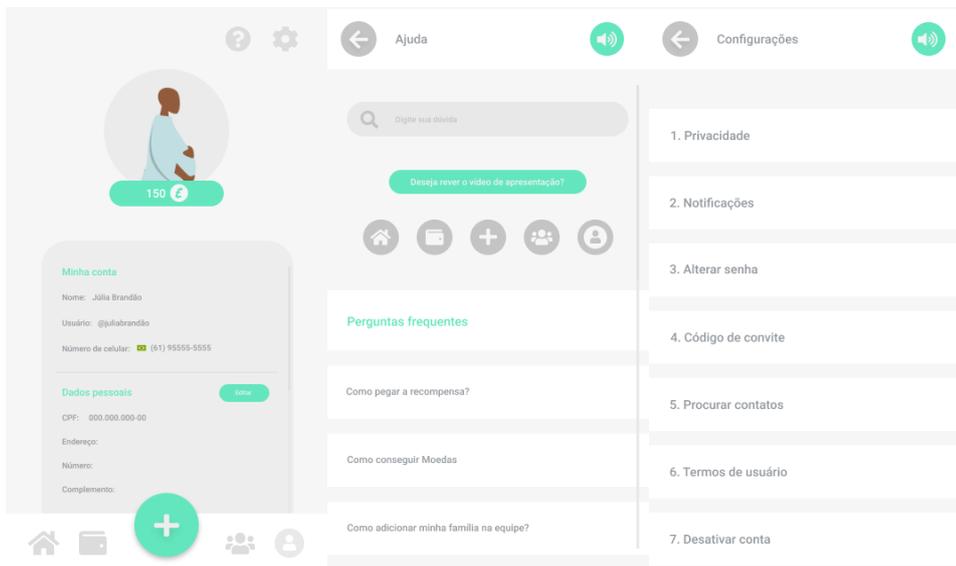


Figure 7.a Profile, 7.b Help, 7.c Settings

4.5.6 Financial Information

By clicking on the button with the plus symbol on the home page "+", it is possible to add the expenses and earnings data of the day (Figure 8.a). The "General" screen shows the available income, the average weekly expenditure, and the expected expense for the month (Figure 8.b). Users can delete the financial records (Figure 8.d) by clicking on the pencil and notebook icon in the upper left corner of the dashboard (Figure 8.c). The dashboard is divided into "Earnings" and "Expenses" and has a table with the date, value and reason for the expense (Figure 8.d). The user can also listen to the dashboard analysis by clicking on the speaker located in the upper right corner (Figure 8d).

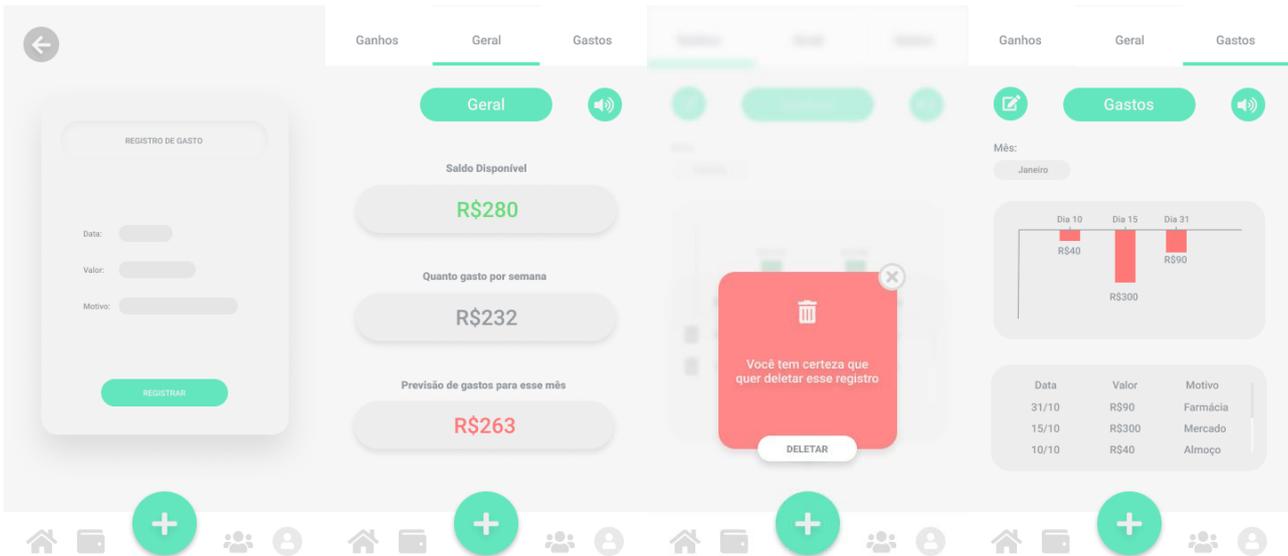


Figure 8.a Financial Input, 8.b General, 8.c Delete Information, 8.c Dashboard

4.5.7 Family and Work Team

The Family and Work Team strategy is responsible for the integration between users. In this section, it is possible to create teams and have visibility of the number of coins of each player.



Figure 9. Work Team

5 Conclusions

This project resulted in the prototyping of a gamified app that helps socially vulnerable communities develop critical thinking and financial management abilities through financial management courses and tool that are made available by the application. Those results were accomplished due to the integration between five problem-based learning (PBL) classes of Production System Project (PSP) of the Production Engineering course of the University of Brasília, whose students worked together to design a solution to participate in the Epic and SDG Challenge, which is a program that takes place every year, coordinated by a group of professors and students from the University of Aalborg, Denmark, and the University of Brasília, Brazil.

Besides the main objective, the project also had the purpose of developing students skills through problem-based learning (PBL) and multidisciplinary critical thinking. Those goals were achieved through the integration

of courses that applied knowledge about project management, quality management, requirements elicitation and product development.

The project was developed based on real needs, in addition to developing a solution to a latent social problem in Brazil, the lack of training on financial management of communities in a state of vulnerability. Students at the University of Brasília had the opportunity to develop their autonomy and creativity, in addition to applying theoretical knowledge learned in the classroom, in a solution that brings value to Brazilian society and cooperates with the strategic objectives of the UN 2030 Agenda.

Due to the social isolation imposed because of the COVID-19 pandemic, the project did not have a validation phase with the target audience, waste pickers from the SLU. As a next step, the study will continue with a hands-on real user experience with waste pickers to validate the application outcome and improve the project's results.

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Seeding future engineers

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Abstract

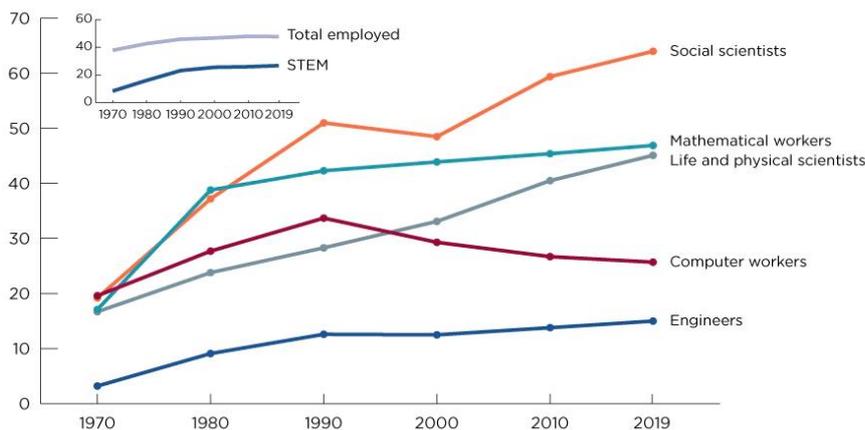
How to motivate female students to progress in the Engineering course? This question was the motivation for this work, which aimed to introduce some women who have revolutionized the world around Exact Sciences to female students attending the Engineering course at the University of Brasilia. This paper presents personal and professional bibliographic results of four extraordinary women scientists in exact sciences: Ada Lovelace, Katherine Johnson, Marie Curie, and Hedy Lamarr and, reports the results of the experience of this work developed in which it concludes benefits of self-esteem, overcoming, courage and appreciation of the female gender, promoting the planting of female engineers.

Keywords: Women Scientists; Female Gender; Motivation; Exact Sciences.

1 Introduction

When we think of physics and mathematics, we remember physicists Galileo Galilei and Albert Einstein, and mathematicians Leonhard Euler and Gottfried Leibniz, for example. In engineering we remember Leonardo da Vinci and Gustave Eiffel. What do they all have in common? They are men in exact sciences. Where are the women in this field? Historical accounts register that it was unusual to have women in the Exact Sciences, because they were prepared to dedicate themselves to domestic chores and were not suitable for this training; and those who had the opportunity to study in this area were because they had family financial support, but the merit of their achievements was not attributed.

Figure 1 presents global statistical data of the most employment sectors for women from 1970 to 2019 (before the start of the COVID-19 pandemic). In 1970, women made up 38% workers and 8% representatives in the STEM fields (Science, Technology, Engineering and Mathematics). By 2019, the STEM proportion had increased to 27% and women made up 48% of all workers, on what women also made up nearly half of those in all math (47%) and life and physical science (45%) occupations.



Source: U.S. Census Bureau, 1970, 1980, 1990 and 2000 Censuses; 2010 and 2019 American Community Surveys, 1-Year Estimates.

Figure 1. Percentage of women in STEM jobs: 1970-2019.

Currently, there has been an increase in the number of female scientists, but they are still a minority and are still not valued in some fields. Why is this? Because career choice is due to cultural factors acquired in childhood and adulthood rather than biological factors (Reis & Silva & Carvalhaes, 2016). For example, toys discriminated by gender, that is, dolls for girls and cars for boys, generating less contact for them in parental activities that have social culture linked to technological and exact themes (Mascarenhas, 2019).

In the studies by Matusovich & Streveler & Miller (2010), they show that the motivation for choosing an engineering course is due to emotional values, acquired beliefs and discovery of personal identity, especially for female students. On the other hand, intrinsic and social motivations are the motivational factors to attract students to engineering education and in addition, women are significantly influenced by their mentors (Kolmos, & Mejlgaard, & Haase & Holgaard, 2013).

Given this situation, the idea arose to expose to the female students of the Engineering course at the University of Brasilia (UnB) some female scientists who revolutionized the world of Exact Sciences with their research, because inspirations come from examples, right?

Thus, the objective of this article is to expose the personal and professional bibliographies of four women scientists (Ada Lovelace, Marie Curie, Hedy Lamarr, and Katherine Johnson) and to report the motivational experience of this exposition for the students of the Engineering course at UnB.

Initially, we will make a documental presentation of these researchers in chronological order. Next, we will report the characteristics of the students involved in the Engineering course, where the work was developed. Finally, we will show the results obtained and the conclusions.

2 Four women who changed the world of exact sciences

In the old days, restrictions on women's access to education were customary and the rare ones who had admission to education could not publish their work because they were expected to be groomed to be only good wives and good mothers and supported by their husbands and furthermore, society labeled that woman were not talented in the exact field like men (Ygnotofsky, 2016). The four women in this article broke rules, learned to listen to themselves and follow their dreams.

2.1 Ada Lovelace

On December 10, 1815, Augusta Ada Byron was born in England-UK, the daughter of poet George Gordon Byron and mathematician Anne Isabella ("Anabella") Milbake - known as the princess of parallelograms. Her parents divorced when she turned one year old. Thus, she lost the paternal bond and started living only with her mother, who was responsible for her education by hiring excellent tutors and for influencing her in exacts. When she was 8, her father passed away, leaving poetry as her second passion, as numbers became her great admiration.

At 17, Ada met the old scientist Charles Babbage who was amazed by her intelligence. At the time he had created the analytical machine (a device like a large clock full of gears for adding and subtracting numbers). He became her mentor and thus began the emergence of the great mathematician Ada Lovelace.

In July 1835, at the age of 20, Ada married William 8th Baron King, Earl of Lovelace, and became known as Ada Lovelace. They had three children, but at the age of 36 due to uterine cancer, she died and at his request, was buried next to her father in Nottinghamshire, a county in England situated in the East Midlands.

After one hundred years of her loss, the poetic scientist's notes on Babbage's analytical machinery have been recognized as a description of a computer and software, i.e., she is the first person to create a computer program that took as its inspiration the punched cards used in mechanical looms at the time.

In her honor and in her recognition around exact sciences, in 1980 the U.S. Department of Defense created the ADA programming language, and since 2009, every second Tuesday in October is celebrated as Ada Lovelace Day, whose goal is to highlight women in science, technology, engineering and mathematics.



Figure 2. Image of Ada Lovelace (Source: https://pt.wikipedia.org/wiki/Ada_Lovelace).

2.2 Marie Curie

Marie Salomea Skłodowska was born on November 7, 1867, in Warsaw-Poland in a period when her country was under Russian rule. From an early age the words "How does this work? What is it? Why is it here? I have an idea" became her jargon. With the death of her mother, at the age of 10, and three years later with the loss of her older sister, she began to dedicate herself more to her studies and to science, which she was fascinated with, but a hidden learning, since women were not allowed to attend universities.

In 1891, at the age of 24, Marie gathered money to attend the Sorbonne University in Paris and it was during this period that she met the scientist Pierre Curie, in which they married in 1895 and became recognized as Marie Curie and had two daughters. They were a couple with a passion for research and together they formed a brilliant team. In the year 1903, they won the Nobel Prize in Physics for the discovery of radiation, which made Marie the first woman to be awarded this prize.

The Curies knew that the effect of the radioactivity was making them ill, yet they did not give up scientific work. In 1906, Pierre died in a carriage accident, and despite great sadness at the loss of her husband, she continued research with the radioactive materials they had discovered: polonium and radium, named after the country of Poland and the sun, respectively. These discoveries led Marie to receive her second Nobel Prize in Chemistry in 1911, making her the first person to have two Nobel Prizes in different fields.

During World War I in 1914, she served as a volunteer nurse driving x-ray trucks to save and help wounded French soldiers. In addition, she proved that radium is a powerful material for cancer treatment. She died of leukemia at the age of 66, leaving great inspirations of courage and fraternity for scientists today.



Figure 3. Image of Marie Curie (Source: https://pt.wikipedia.org/wiki/Marie_Curie).

2.3 Hedy Lamarr

Hedy Lamarr is the stage name of Hedwig Eva Maria Kiesler, an Austrian born on November 9, 1914.

From an early age, her beauty was admirable, which made her win several beauty contests and start her artistic career at the age of 16. She had a very controversial personal life, was married six times, and had two children with her third husband, John Loder. In addition, most of her husbands were wealthy and influential politicians, for example, her first husband, Friedrich Mandi, in which she attended his meetings with researchers and scientists that awakened and revived her interest in technological research.

In 1940, during World War II, Lamarr patented her first invention: a radio interference device to alter Nazi torpedoes; the idea for which came about together with composer and friend George Antheil. This work was

the basis for the creation of wi-fi, Bluetooth, GPS, and military communication, i.e., she co-invented the technology to use frequency hopping spectral scattering (FHSS).

In the last years of her life, she lived alone and did not like visitors, died at the age of 85 residing in Florida-USA, received several awards in life and fourteen after her death, in 2014, entered the National Inventors Hall of Fame.



Figure 4. Image of Hedy Lamarr (Source: https://pt.wikipedia.org/wiki/Hedy_Lamarr).

2.4 Katherine Johnson

On August 26, 1918, African American Katherine Coleman was born in the small town of White Sulphur Springs, USA. Due to the racial segregation of the time, she had many prejudices and difficulties in accessing education, but this did not hinder her dedication to her studies.

At 15, she entered the university and was tutored by W. W. Schieffelin Claytor, the third African American to earn a PhD in Mathematics. In 1939, Katherine at age 18 finished her undergraduate degree and was the first black woman to complete a college degree.

In 1929, she interrupted her professional career to devote herself to her marriage and the three daughters she had with her first husband James Francis Goble. In 1956, Katherine was widowed and, remarried in 1959 to Lieutenant Colonel James A. Johnson, and became known as Katherine Johnson.

She returned to research in 1953 working for the U.S. Aerospace Department (now the National Aeronautics and Space Administration - NASA), where she was responsible for man's flight to the moon in 1962. He then dedicated himself to space work for NASA and retired in 1986, after 33 years of dedication to mathematics for aerospace engineering. He received several awards and honors before he passed away on February 24, 2020, at the age of 101, including the Presidential Medal of Freedom.



Figure 5. Image of Katherine Johnson (Source: https://pt.wikipedia.org/wiki/Katherine_Johnson).

3 Description of the experience

In 2021, the idea of planting, sowing, and motivating female students emerged from the author's concern with their demotivation in dropping out of the Engineering course at Faculdade do Gama (FGA), during the period of the pandemic caused by COVID-19. FGA is an extension of the University of Brasilia (UnB) of Brazil, in which it offers five engineering courses: aerospace, automotive, electronics, energy and software.

For this reason, an extension project entitled "Mathematical café for future female engineers" was created, which took place in the period from May to December 2021 with weekly meetings in virtual format with the participation of 50 students, in which the themes were directed:

- A bibliographical exposition of personal and professional women who have made historical contributions and revolutionized the significant role in the engineering courses offered at FGA.

- The presentation of curious historical facts in the world of Exact Sciences.
- Emotional themes to mitigate the period of social isolation due to the COVID-19 pandemic, such as: anxiety, depression, phobia, nostalgia, fear, etc.



Figure 6. Logo of the extension project Math Café for future female engineers.

4 Results and Analysis

To collect data from the extension project presented, the female students who participated in this activity answered a brief questionnaire (voluntarily) that addressed the following questions:

- Did the presentation of women who shone in exact sciences motivate you to continue in the Engineering course?
- Did your perception of the Engineering course change positively with the exposure of the female scientists of the project?
- Were your emotional problems arising in the isolation period because of the COVID-19 pandemic successfully alleviated?
- Did you enjoy participating in the project?
- Among the four scientists studied, which one did you like the most? Why?

In addition, the questionnaire had a space for open answers so that the students could give their opinion, suggest and/or criticize. Thus, the scale dimensions ranged from 1 (strongly disagree) to 4 (strongly agree).

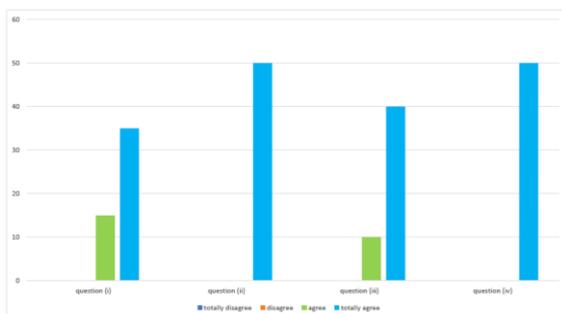


Figure 7. Questionnaire response - questions (i) to (iv).

Based on Figure 7, it can be concluded that most of the students considered that the exemplification of outstanding women in exact sciences motivated them to continue in the course (35 votes = 70%) and that their perceptions/notions of the Engineering course became clearer and more motivating (100%). The emotional themes worked on helped overcome the period of isolation experienced by the COVID-19 pandemic (40 votes = 80%) and unanimously, all participants enjoyed participating in the project (100%).

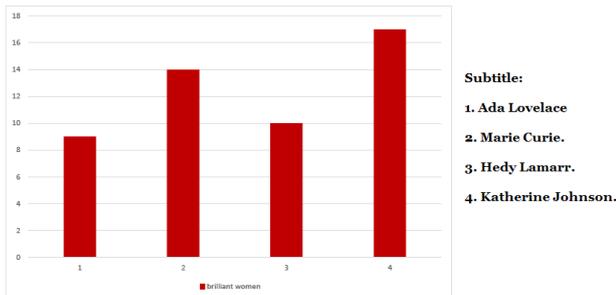


Figure 8. Answer to question (v).

Figure 8 presents the scientists favored by the participants. Thus, listed in descending order were Katherine Johnson (17 votes = 34%); Marie Curie (14 votes = 28%); Hedy Lamarr (10 votes = 20%) and Ada Lovelace (9 votes = 18%), respectively, the justifications were: example of race and courage; example of fraternity and love for science; example of beauty and intelligence; example of achievement and conquest.

Below are four randomly open responses from some participants:

- Student 1: "The participation in this project was a great motivation for me to keep in my Engineering course. In particular, highlight the example of scientist Marie Curie who encouraged me to study what I love and not be afraid to always research what I don't know."
- Student 2: "The project brought me a different perspective on women's skill in Exacts. I had my hope renewed and my emotional worth. In addition, meeting all these women scientists are certainly great motivational examples to attend the Engineering course."
- Student 3: "Katherine Johnson and Hedy Hamarr were the scientists who motivated me the most, as they were distinct examples of economic class and race, but both had courage and fought for their dreams. Exacts are also for women!"
- Student 4: "The women scientists studied in this project improve my conception of myself, that is, my values, my beliefs and my goals. In addition, the stories of these great women motivated me to have courage in my choices and find the strength to never give up on my dreams."

According to the data presented, it can be concluded that the personal and professional bibliographic study of women scientists in the Exact Sciences was a great motivator for the permanence of female students in the Engineering course, because women scientists were sources of inspiration and intrinsic motivation, which converges with the results of Kolmos, & Mejlgard, & Haase & Holgaard (2013). In particular, it is highlighted that the values (captured from the brilliant women scientists studied): autonomy, mastery, purpose, courage, achievement, perseverance and creativity, were sown, planted and will certainly always be cultivated by the students participating project.

Therefore, it is concluded that real inspirations from women scientists who made history and shone in the field of exact sciences can successfully attract women and/or young people to engineering with female empowerment.

5 Conclusions

With the results obtained in this study, it was possible to observe that the students were motivated and excited to stay in the Engineering courses at FGA, due to the many real-life accounts of female scientists who revolutionized the area of Exact Sciences. The approach presented cleared up doubts and exposed curiosities in the universe of exact sciences that stimulated the participants' curiosity. The emotional themes brought emotional comfort for the period of isolation due to the 2021 pandemic of COVID-19.

The scientists presented mirrored in the students the joy of fundamental discovery, awakening the feminine touch of each within themselves (Swaby, 2015). As such, it is believed that exemplifying women in exacta enables a great benefit to plant and sow fruits of motivation, self-esteem, courage, overcoming, female empowerment, and confidence so that SHE can follow the brilliant paths that these pioneers once explored.

For future activities, it is intended to carry out a local and global statistical survey on factors that are capable of awakening more women in the exact sciences, especially in engineering.

Acknowledgements

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Conducting a Home Experiment Related to the Colligative Properties of Chemical Solutions.

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Abstract

The experimental part of teaching chemistry in a series of laboratory activities complements the fundamental learning of the various topics covered in a chemistry course. However, alternatives are necessary when situations arise where it is impossible to have a chemistry laboratory. Conducting home experiments can be of great help in teaching various chemistry topics, as they can be used in tasks, research scenarios, and alternative laboratory practices. They can be applied to different levels of teaching depending on their orientation and the contents they address. In the absence of a laboratory to conduct chemistry practice experiments due to Covid-19 faculty and student confinements at home, we developed feasible practices to do at home with ordinary homemade materials that were not risky or dangerous. We selected solutions with desired colligative properties. Thirty engineering students taking two university chemistry laboratory classes participated, coming from programs in the chemical area such as chemical engineering and biotechnology engineering, among others. The teaching-learning process was conducted remotely via Zoom. The students appreciated the in-home practices. Motivated to understand the topics, they performed well on the exams and the laboratory reports and issued high opinions of the classes in the student survey.

Keywords: Concentration, solutions, colligative properties, higher education, educational innovation

1 Introduction

Chemistry courses are part of the curricula of most engineering careers in the various institutions of higher education, such as Tecnológico de Monterrey or the Autonomous Metropolitan University. They are usually composed of theoretical and experimental parts, the latter occurring with practices of specific course topics in a chemistry laboratory.

However, it is not always possible to have a chemistry laboratory for the experimental phase of a chemistry course due to unforeseen (or even foreseen) situations for social, administrative, or medical reasons.

In this case, technological tools such as the Zoom videoconferencing application can facilitate convenient and effective remote teaching when the traditional face-to-face teaching modality is impossible.

Also, laboratory activities can be adapted to take place outside of physical laboratories to meet the objectives of the experimental phase of the chemistry courses. In this study, we sought to work with topics on solutions and their colligative properties, which are taught in chemistry courses at different levels.

2 Theoretical Framework

Conducting experiments related to the colligative properties of solutions to support the theoretical content is part of the chemistry curricula at different academic levels.

The four colligative properties are a) the decrease in the vapor pressure of a liquid (P°), b) the increase in boiling temperature (t_b), c) the decrease in freezing temperature (T_f), and d) osmotic pressure (π). They only depend on the number of solute particles in the solution and not on the nature of the solute particles (Chang, 2002).

This work focused on practices related to the colligative properties of solutions and specifically on increasing boiling temperature (Δt_b) and decreasing freezing temperature (ΔT_f).

Both the increase in boiling temperature and the decrease in the freezing point are proportional to the molal concentration (m) of the solution and an ionization factor " i " (the van't Hoff factor). The proportionality constants are K_b (molal constant of boiling point elevation) and K_f (molal constant of the decrease in freezing point), both with units of $^{\circ}\text{C} / m$. Therefore:

$$\Delta T_b = i K_b m \quad (1)$$

$$\Delta T_f = i K_f m \quad (2)$$

The Van't Hoff factor (i) is related to the solutions that form electrolytes since these dissociate into ions, separating into two or more particles, which are the ones that determine the colligative properties of a solution and can be defined as:

$$i = \frac{\text{Actual Number of particles in the solution after the disassociation}}{\text{Number of moles dissolved initially in the dissolution}}$$

Table 2. Regarding the molal constants of boiling point elevation and the freezing point decrease of several common liquids, both K_b and K_f only depend on the solvent (Chang, 2002)

Solvent	Normal freezing point ($^{\circ}\text{C}$)	K_f ($^{\circ}\text{C} / m$)	Normal boiling point ($^{\circ}\text{C}$)	K_b ($^{\circ}\text{C} / m$)
Water	0	1.86	100	0.52
Benzene	5.5	5.12	80.1	2.53
Ethanol	-117-3	1.99	78.4	1.22
Acetic acid	16.6	3.90	117.9	2.93
Cyclohexane	6.6	20,0	80.7	2.79

This implies that in non-electrolytes (covalent solutes), the van t Hoff factor has a value of one. A strong electrolyte such as CaCl_2 will optimally have a value of three because this compound is ionized in a calcium particle Ca^{+2} and two particles of chlorine Cl^{-1} .

Table 3. Van't Hoff factor for 0.05 M electrolyte solutions at 25°C (Chang, 2002)

Electrolyte	i measured	i calculated
Sucrose (is not an electrolyte)	1.0	1.0
HCl	1.9	2.0
NaCl	1.9	2.0
MgSO_4	1.3	2.0
MgCl_2	2.7	3.0
FeCl_3	3.4	4.0

This table presents the values of i , measured experimentally and those calculated assuming a complete dissociation. They are similar. There is no appreciable formation of ionic pairs that do not have a net charge and reduce the number of particles in the solution.

3 Background

The colligative properties experiments and others are covered in a laboratory manual for a chemistry laboratory equipped with the appropriate materials (Serrano, 2020). However, if a physical laboratory is not available, experiments can be conducted virtually (Infante, 2014), (Vega, 2016). Moreover, we contemplated an alternative practice that could be carried out in any home (Zapata, 2020).

Zapata (Zapata 2020) promotes experimenting at home with homemade materials usually found in a kitchen. Although these experiments do not require chemistry laboratory equipment such as beakers and specimens, they require a thermometer to measure the solution's boiling temperatures and freezing points, which is not an instrument usually found in a house. If the home does have a thermometer, it is usually a clinical one, and its temperature measurement range is not sufficient to measure the temperatures involved in experimental practices.

Well (Well, 2004) and Braga (2022) explain that you do not need a laboratory built for specific purposes or a closet with specialized and expensive equipment to perform chemistry experiments. Most can be carried out with simple materials found in the kitchen, the bathroom, and the pharmacy or convenience stores. However, they do not mention an experiment that involves temperature measurement.

4 Proposal for the home laboratory practice

To develop the various course practices, teachers, as far as feasible, can simulate chemistry laboratory experiments and provide tutorial videos from various educational institutions (Chen et al. 2013), (Infante 2014), (Vega et al. 2016) related to the topics to be discussed. These can be available to all on the network. In addition, educators can design no-risk experiments adapted to the program contents to be performed in the students' homes with household materials while maintaining the level of knowledge established by the course objectives.

Considering the difficulty of measuring a solution's boiling and freezing temperatures in a home experiment to teach colligative properties, we looked for a parallel variable proportional to the difference in boiling and freezing temperatures between a pure liquid and a solution formed by it.

Since the solute content in a solution causes it to boil at a higher temperature than the pure solvent, according to equation (1), we contemplated measuring the time the pure solvent boils and the time to boil the solution. This time difference would be proportional to the temperature difference. Thus, using the same solvent and different solutes, it could be deduced which would have higher ΔT_b and, therefore, higher boiling temperature, considering the same molal concentrations in all cases.

For example, suppose an aqueous solution A takes 400 seconds to start boiling, a solution B 450 seconds and water alone 300 seconds. In that case, it could be concluded that solution B has a higher boiling point than solution A and, therefore, a higher ΔT_b , which would constitute a starting point for the student to analyze the observed phenomenon and its implications.

According to equation 2, something similar could be done to determine which solution would have the lowest freezing point and the highest value of ΔT_f . In this case, it would be more complicated to determine the freezing times of the solvent and the solutions used in the experiment.

5 Methodology

The students in two classes of 30 each studying this subject were instructed to mark a glass at a given height above the middle and obtain a small measuring spoon in their house. Otherwise, they could get the lid of a jar as small as possible and three equal soft-drink bottle caps or something similar.



Figure 1.

They were told to fill the glass with tap water to the mark on the glass and place it in another similar glass. The students were then asked to refill the glass with water to the indicated mark, add two sugar measures with the measuring spoon, shake it to dissolve evenly and place the formed solution in another glass. Next, they were instructed to repeat the same procedure but add a measure of salt to the marked glass so that the identical amounts of water, sugar solution, and the saline solution would be in the first, second, and third glasses, respectively.



Figure 2.

The students were then asked to carefully fill a bottle cap with the liquid from each glass and place them in the kitchen freezer, long enough for the solutions to freeze.



Figure 3.

Next, we instructed the students to pour all the contents of the first glass into a pot and place it on a kitchen stove burner to observe how long it took for the water to boil. At the end of the experiment, they emptied the pot, rinsed it, and allowed it and the stove to cool. Then, they were to repeat the same procedure with the solutions in the other two vessels, trying to maintain as much as possible the same process conditions.



Figure 4.

Finally, they were asked to explain and justify what they had obtained and observed during the performance of these home chemical experiments in the laboratory report used in each practice.

6 Results

All the students reported that the time to reach boiling in the saline solution was more than the sugary one, which, in turn, was longer than the pure water. Moreover, the latter was the first to freeze, then the sugar water, and finally the saline solution much later; some even pointed out that the salt solution did not freeze.

75% of them explained that sugar was a covalent compound and that salt was ionic, which was the reason for the difference in the times obtained. 62% correctly contemplated the van t Hoff factor concept. Only 28 % tried to apply specific numerical calculations to justify the experimental process, concluding that more particles were dissolved in the saline solution than in the sugary one.

In a series of interviews, most of the students opined that this activity had awakened their interest in the subject but found it challenging to understand. Something similar happens in problem-based learning or research, even when it involves simple things of daily life.

At the end of the course, all the program topics were analyzed. 81% of the students solved the problem related to colligative properties with a level of difficulty similar to other tasks and exams of various chemistry courses that most students considered too complex to understand.

7 Conclusions

In the absence of laboratories to conduct experimental practices of a chemistry course for any reason, one can turn to virtual technological supports such as simulators and descriptive videos, which are undoubtedly very useful. However, alternative practices with materials commonly used at home can complement these activities so that the student feels the closest possible to the activities and methodology in a laboratory.

All the students liked doing the home-based activities for the level of rapport and presence they felt, unlike watching a descriptive video or tutorial where there could be a certain degree of dispersion at any given moment. The home experiments motivated them to study the subject, investigate, and understand the

observed chemical phenomena; some even proposed that similar home activities be developed in other practices

Conducting chemistry experiments of this type is economical and feasible outside a laboratory's scope. Depending on the teacher's management and approach, they do not detract from the quality or level of knowledge in the significant learning of one or several topics.

While in this case, the work was developed as an educational response to unexpected home confinement for the entire population, including students and university professors, the methodology could also be used in everyday teaching of theoretical chemistry courses.

It would be convenient to continue developing experimental activities of this type for various topics of chemistry courses for the educational benefit that they can entail.

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An advanced application for learning robotics using Augmented Reality

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Abstract

Robotics is a multidisciplinary branch of engineering that nowadays presents many challenges to overcome for having a greater presence and impact in our society. Due to its characteristics, usually it is investigated by the integration that it can have with other technologies and one of these is augmented reality (AR), which consists of combining the real and virtual world through computer processes, improving the visual experience and the scientific application. The main objective of this project is to develop an application that implements AR for the visual projection and supervision of robots, where the solution is based on a client-server architecture. The server is responsible for controlling the robot using ROS (*Robotics Operative System*), and the client is based on a platform compatible with Unity that includes the AR Vuforia engine, including the characteristics of graphic, physical and AR simulation of the robot to be controlled. To bring about this investigation it was used a configured Windows 10 environment with WSL (*Windows Subsystem Linux*), allowing ROS and Unity to coexist on the same machine, meanwhile, to overcome the communication challenge that exists between them, it used the solution proposed by the Unity Robotics Hub project. This software permits to add three robot models with distinctive characteristics to recreate some use cases with AR. Finally, it is possible to obtain an independent Unity client based on UWP (*Universal Windows Platform*) oriented to desktops and with AR functionalities.

Keywords: Robotics; Augmented reality; Robotic Operative System (ROS); Unity, Vuforia, Ros #, Unity Robotics Hub.

1 Introduction

Robotics is a multidisciplinary branch of engineering that currently presents many challenges to overcome in order to have a greater presence and impact in our society. The research drives the current state of this branch with new improvements that are always being sought by collaborating with technologies from other environments to enhance current robotic solutions and one of them is augmented reality (AR).

Augmented reality (AR) is a variation of Virtual Reality (VR), where the user can see in the same environment how real objects and the superimposition of virtual objects coexist (Azuma, 1997). This offers the improvement of our perception by helping us to see, hear and feel our environment in new ways (Krevelen, 2007). The AR potential can be used in multiple areas and it also helps to improve interaction difficulties in current challenges. Some examples about this application cases are:

- In an industrial manufacturing environment, the management of a production line can be supported by visual indicators to know some parameters such as the state of operation, quality control of the products, alerts that include the location of a possible failure in any component of the line.
- In the field of medicine, doctors can speed up the process of diagnosing a physical injury in a patient while obtaining real-time visual feedback from a virtual projection over the affected area with the respective bones in that area.
- For entertainment, focusing on video games, the user experience can be enhanced by including features that use real physical effects in conjunction with the 2D/3D elements of the video game itself.
- For educative environment, simulations is a commonly tool to avoid some executions of experiments because doing them with real equipment and components can be significant expensive, so this is where AR offers an improvement in the student experience that can observe a better physical interaction between two virtual 3D elements in an already existing and easy to manage real environment.

In the field of applications of AR its notable the intention of integration with robotics, which offer the enhancement of existing solutions in multiple areas and the experimental research. Currently there are already several investigations that study these characteristics:

- Improve the navigation control of mobile robots using head mounted displays (HMDs) and AR (Kästner & Lambrecht, 2019). In this case tests were carried out using a pair of Microsoft HoloLens that allow the user to indicate the displacement positions of the robot with hand gestures, these are transmitted to the robot's operating system to be processed and executed, in addition to giving user trajectory planning feedback.
- Facilitate the teleoperation of aerial robots (Hedayati, Walker, & Szafir, 2019). In this case they used a commercial drone and a pair of Microsoft HoloLens, where a user get this equipment and obtained details feedback about robot vision with other perspectives that helped flight operation.
- Improve trajectory planning with AR-based interfaces (Fang, Ong, & Nee, 2013). The authors exposed some of the difficulties of human-machine interaction, making a specific focus on industrial robots and how these can be very limited to the use of the programming languages of each manufacturer, especially in relation to trajectory planning, but through AR they managed to develop an interface oriented to the use of a cubic marker that allows managing the points of the desired trajectory. Two aspects of this development can be highlighted: first, the use of the cubic marker that has several targets associated with it, so that when it is identified by the camera, it executes an action on the indicated point, and the use of a method based on Euclidean distance to resolve and assist to the user during point generation.
- Planning and simulation of a robotic cell using AR (Pai, Yap, & Singh, 2014), in this research the authors use some technologies to find alternatives in the planning process of a future robotic cell installation, offering a cost reduction and increased efficiencies that are representative for small and medium-sized businesses. The cell that they recreate to simulate the manufacturing plant environment is made up of a robotic arm, a conveyor belt, a pallet and a numerical control machine (CNC), with the aim of recreating material handling processes. An interesting point that should not be overlooked are the technologies that were used, such as a HMD as vision equipment and an interface based on C++ with OpenGL through ARToolKit to generate the virtual elements, as well as a target for everything related to the interaction of the user.
- Teleoperation of a manipulator-type industrial robot based on AR (Solanes, et al., 2020), this paper seeks a considerable improvement in the teleoperation of this type of robots, which are common in manufacturing areas and for this reason makes it relevant to improve their management. Regarding the hardware, they use a game controller (gamepad) and a HMD which receive the feedback from the control carried out on a robotic arm. For the development of the interface, they use Unity and Visual Studio on Windows 10, managing to generate an application for the HMD with the MixedRealityToolkit in Unity. The results showed the benefits of a control feedback to enhance the user experience.

2 Software architecture

In this research we used some technologies such as 3D objects render, robotics controls, AR and communications between software components. Some of these technologies don't have any compatibilities between them therefore it was a huge challenge to resolve as real time communication.

2.1 Technologies and tooling

- OS Windows 10 – Enterprise Edition
- Ubuntu 18.04 LTS over WSL (Window Subsystem Linux), specifically WSL 2 in W10
- ROS (Robotic Operative System) Melodic, corresponding version in Ubuntu 18.04
- MoveIt, open-source framework for controlling robots in ROS
- Robot's models in URDF (Universal Robot Description Format); UR3, HOAP3 and Shadow Hand (Figure 1)
- Unity, a world class game engine

- Visual Studio 2019 or latest
- Vuforia, AR engine
- Unity Robotics Hub, library for communicate ROS and Unity, predecessor of RosSharp project
- UWP (Universal Windows Platform), target platform for client out Unity environment
- Webcam (1920 x 1080p, 30 fps)



Figure 1. Real robots model used in this project: (Universal Robots, 2021; Galdeano, Chemori, Krut, & Fraise, 2014; Galdeano, Chemori, Krut, & Fraise, 2014)

2.2 Integration

In design process the best software architecture for this solution has a client-server approach, therefore the classification for each component was grouped in infrastructure, server, client and communication components (Figure 2):

- *Infrastructure*: based in W10 OS and extra layer with WSL 2
- *Server*: which has the responsibility to process all robot movements and calculate trajectories with MoveIt in ROS (programmed in Python). This layer run over Ubuntu 18 in WSL into the same machine
- *Client*: who has the AR features and 3D renders in Unity combined with Vuforia engine in the develop environment; in production case all this client runs in UWP. All logics for this layer was coding in C#
- *Communication*: to resolve the interaction between client and server was necessary to use libraries from Unity Robotics Hub, allowing the communication with TCP socket in real time and low latency.



Figure 2. Architecture solution with all key components

The default robotics models are in URDF, this format is ROS oriented but can be transformed with a package from Unity Robotics Hub called *URDF Imported* which generate a robot model into the Unity scene with all visual and physics properties, including the joints as articulation bodies allowing an easier control. Another key

library in this solution is *ROS TCP Connector* for client side in Unity and *ROS RCP Endpoint* for ROS server side, both are from Unity Robotics Hub and allow the communication.

3 Experiments

There were designed three experiments with the aim of testing the previous environment. Attempt to recreate real life process with some popular robotics model and all cases the logic structure is the same both on the client and on the server (Figure 3).

For AR features, Vuforia engine has many ways to detect and render the Unity model in real time video from camera device. The selected way was focused on detect targets features mainly with *VuMark* (a special image with high contrast and optimized to be detected) and the render action succeed when the camera's scan detected the established target in the real environment.

On the client side the general execution process renders the robotic model when a trigger is activated because the camera's scan detects a target on real environment, after this the robot is ready to go to the next state (movement combination), when pressing the respective button, the actual state and next state data is sent to the server endpoint. On the other hand, the server waits for client request, once it has arrived the request data about robot state (robot's joints and next request state) redirect this data to mover service which processes it with a robots model previously charged in a *MoveIt* node (with all movement restriction and config to calculate trajectories), if the next state doesn't have collisions or trajectories errors, this service generates an output with the new position coordinates and return them to the client. Finally, the client executes the movements in visual model until robot has the final state.

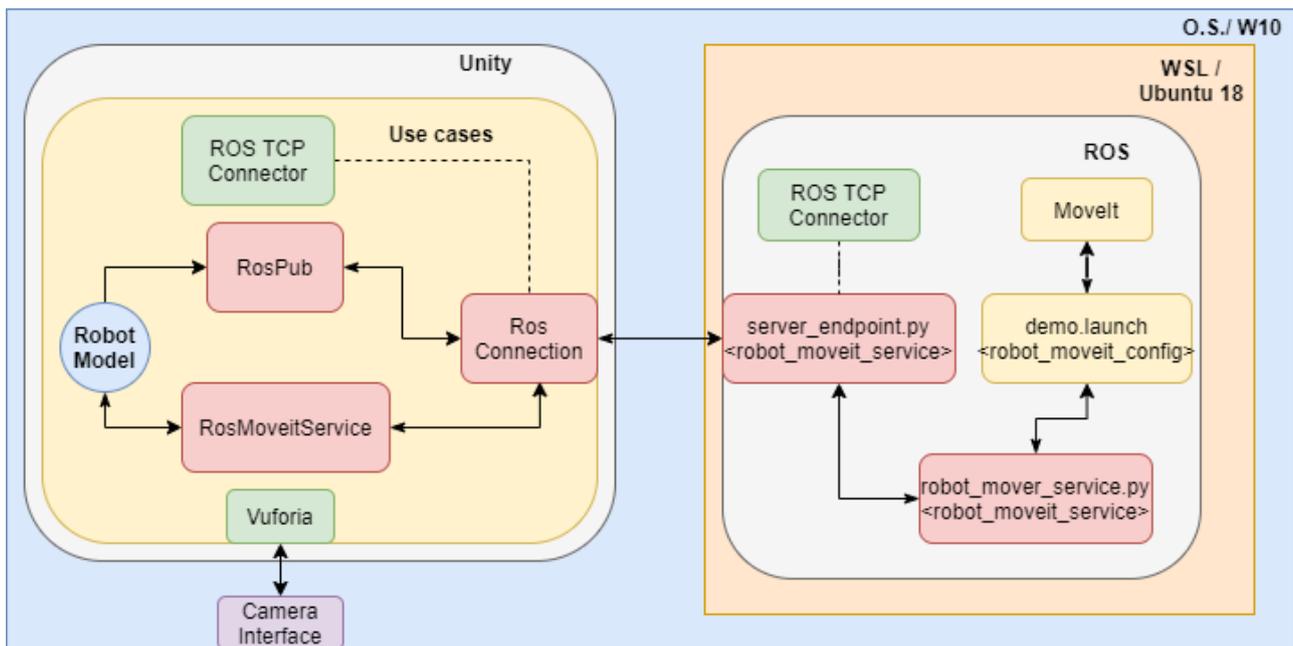


Figure 3. Software components, modules and relationships in client and server

3.1 Pick and place with a robotic arm

A typically pick and place process was designed with a robotic arm UR3 from Universal Robots and pneumatic vacuum suction cup in the extreme of the robot arm. This experiment has 4 states or positions and just one trigger. Where robot begins its initial state, it picks a box up, moves it to the opposite direction and places it in the green zone (Figure 4).

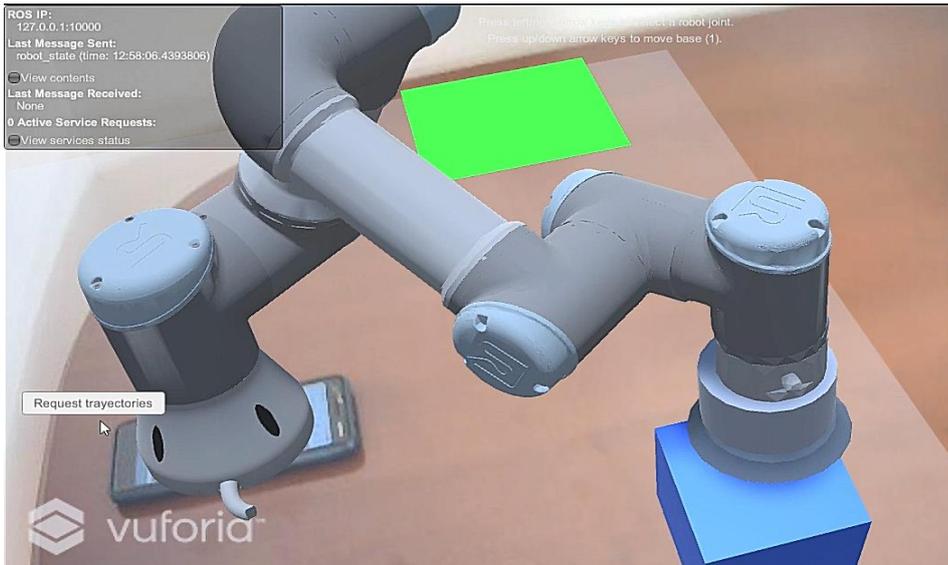


Figure 4. Pick and place process with UR3 and target

3.2 Robotic humanoid control

The control for humanoid robot is complex, but an adjustment was made to remain the torso fixed at a certain coordinate. It allowed to use the robot HOAP3 from Fujitsu. This experiment has 3 independently states associated to each body part and each one has its trigger, when all triggers are executed, the robot copies an equilibrium position on one foot (Figure 5).

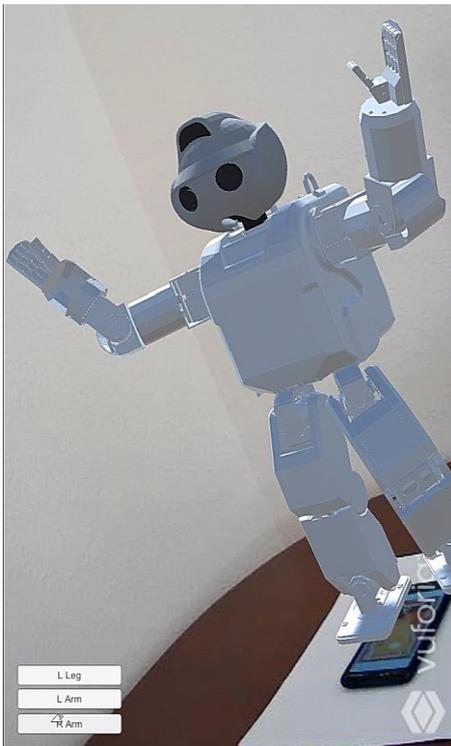


Figure 5. Robotic humanoid control with HOAP3

3.3 Grasping with robotic hand

Shadow Hand form Shadow Robot was selected to realize the grasping activity. This experiment has 2 independently states, pre-grasp and post-grasp, when all stages were completed, the robot catches the cylinder from its initial position to another final opposite position (Figure 6).

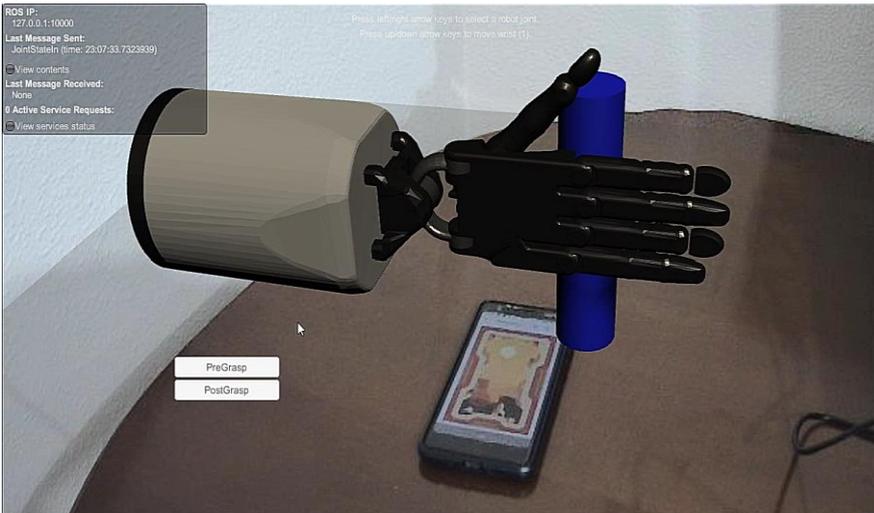


Figure 6. Grasping process with Shadow Hand

3.4 Client app in UWP

Unity is mainly used for development stage, but it can compile to target device when the app will be executed, in this case the limitation is about Vuforia engine compatibility, this one only works with mobile devices (Android, iOS) and UWP, but the research scope is about the development in the same machine, therefore UWP was selected as production target, because it allows to execute the app in desktop with W10.

To improve the user experience, a main menu was included in the app, which groups all the experiments in AR and virtual version (Figure 6 and 7).

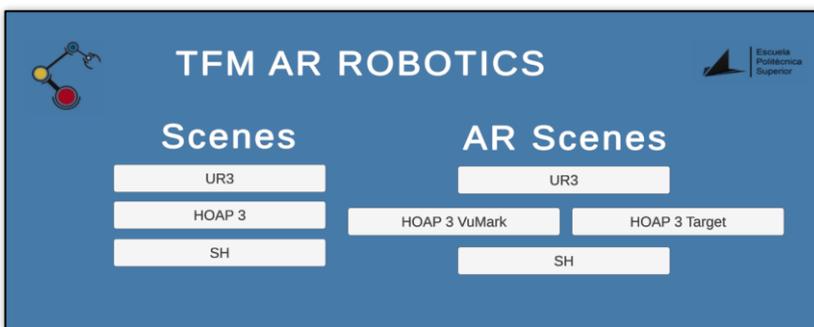


Figure 6. Main menu for all experiment in UWP

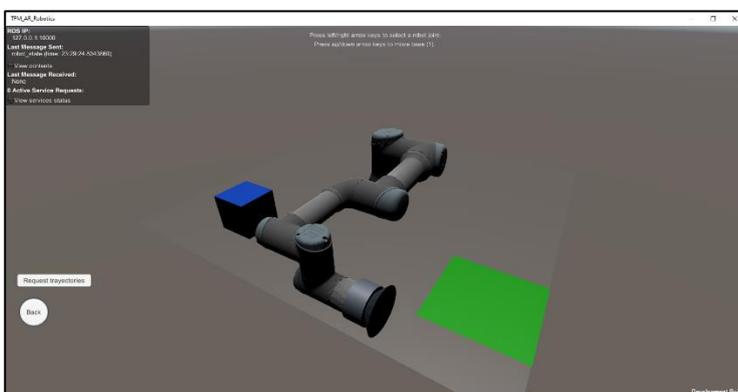


Figure 7. Scene pick and place with robotic arm without AR

4 Benefits in the learning process

It is worth pointing that this research also has some positive insights for learning process focussed on robotics students or similar in related areas, this is the case for the degree in Robotics and the master's degree in Automatic and Robotic students in University of Alicante.

The technologies and techniques tested here could be used for designing some new experiments in laboratories or interesting workshop, being able to have the following advantages:

- Configuring the develop environment with only one personal laptop or desktop, because these experiments use ROS in WSL as backend and Unity in W10 as client both in the same instance
- Learning about robotics physics with robot models in Unity, this allows to test some full featured models in an easy way with URDF file from real models
- Practicing the control algorithms over robots with ROS and planning trajectories with MoveIt framework
- Improving technical skills in programming languages as C# in Unity and Python or C++ in ROS
- Demonstrate a way to build new robotics products with AR, due to is possible generate a standalone apps with external and enterprise grade frameworks

5 Conclusions

After performing the iterations and preparing the development environment for this research, the conclusions would be the followings:

- The AR development environment for using W10 as S.O. base to support Unity and WSL, the latter allows the use of Ubuntu distribution with a ROS respective version, which is a viable alternative to avoid virtual machines by third parties in Windows, due to its easy configuration and compatibility with graphics recourses
- Unity and Vuforia are good options to develop interfaces with AR, both are allowed to do a project with three use cases with different based robotic models: UR3, HOAP3 and Shadow Hand. The iterations and the proof of concept had generated many scenes with and without AR in a modular way. It is worth mentioning the power of Unity to export multitarget clients. In this research was generated an UWP app which is ready for production environment, doesn't need Unity installation in destiny device and it is easy to distribute
- The communication between a ROS node or server with an app client based in Unity is not native but exist some solutions to mitigate this complexity. The projects in Unity Robotics Hub were a key component as well as it integrates a two-ways communication and uses ROS's message scheme to generate standard or custom messages
- The communication components and the architecture for this application allowed the response with information state and the coordinates to the client (with a previous services validation with MoveIt) then the client was independently getting this data and executing the movement with scene and physical restriction in Unity (all workload belongs to client side)
- Around benefits in learning process, this research has many resources to build practices in laboratories or make some workshops about robotics and AR, where students can learn more about these topics with practical examples and reinforce other knowledge areas which as: programming languages, algorithms, networks, 3D modeling and some others.

In future researches and projects will be interesting to consider other topics as: limitations of Articulation Body components in Unity, improvement of the AR experience with better hardware features, to make tests and integrations with mobiles devices and to use container technologies as Docker for development and deploy ROS nodes.

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The Torca Experiment: A model of transdisciplinary project-work

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Abstract

All of Colombia's major cities have at least one higher education centre. However, this does not necessarily entail fair access to education for those living outside these cities' main urban areas. Moreover, financial difficulties and the problems inherent to a long commute are often insurmountable barriers for people who want to study but live in comparatively remote regions. To tackle this issue, the Universidad Nacional de Colombia (UNAL) created a particular admission program (PEAMA) to facilitate access to education in this less-favoured population sector. Since the academic interests of any population will be varied, the UNAL offers selected educational programs through the PEAMA. Thus, professors and lecturers are sent to schools that effectively function as nodes of the UNAL in rural areas to allow students to complete the first four semesters of their program of choice. During the first semester of 2022, 15 people from the rural area of Torca in Bogotá decided to begin their higher education studies through the PEAMA. In total, seven different academic programs were chosen. To allow as many students as possible to complete their programs, a transdisciplinary project-based learning model focused on the particular social problems of the community was designed and implemented for that specific case. Thus, three multidisciplinary groups were created to accommodate the 15 students enrolled in the university through the PEAMA: one for students from the literature and philology programs, one for students of economy, agronomy, and the social sciences, and, finally, one for engineering students. This article discusses the model and the first results obtained.

Keywords: Project-based learning, transdisciplinary, humanitarian education, rural

1 Introduction

In 2007, the Universidad Nacional de Colombia (UNAL) started implementing the PEAMA, a special admissions program designed to facilitate access to education for specific population sectors in the periphery of its areas of influence. Initially, the PEAMA was devised to allow students of the periphery campuses of the university, i.e., those in Arauca, Leticia, San Andrés Islas and San Andrés de Tumaco, to enrol in programs offered only in its major campuses, i.e., those in Bogotá, Medellín, Manizales and Palmira. Thus, the students of the periphery campuses would have the chance to study programs that would otherwise be out of reach for them (Acuerdo 025, 2007).

Students admitted to this program completed their undergraduate degrees in three stages. In the first stage, they took the introductory courses of their program of choice in their place of origin. Then, after their fourth semester of studies, they went to one of the main campuses of the university to continue their studies there. Finally, they returned to their places of origin during their last semester to write a thesis or implement a project focused on their territories.

Due to the positive reception of the program and its favourable impacts on students from the periphery campuses of the university, the PEAMA was extended in 2015 to start offering the same services to people who lived in comparatively remote areas that, nevertheless, fell into the regions of influence of the major campuses of the university (Acuerdo 201, 2015). Since there were no periphery university campuses in those areas, professors and lecturers from its main campuses were sent to some rural schools that would effectively begin to function as nodes of the UNAL. Thus, in 2016, the PEAMA Sumapaz was created to allow the people that lived in Nazareth—about 84 km south of Bogotá, in the lower part of the Sumapaz paramo—to enrol in some of the programs offered at the Bogotá campus of the UNAL (Alcaldía Local de Sumapaz, 2022). At that time, the university provided 60 PEAMA spots, of which 18 were taken. Those students chose the following undergraduate programs: nursing, agricultural engineering, agronomic engineering, veterinary medicine and zootechnics. Later, in 2018, the PEAMA Sumapaz program expanded further to allow students graduating from

several rural schools in Bogotá to study at the UNAL. The number of undergraduate programs that could be chosen was also increased (Resolución 405, 2016; Resolución 908, 2018). Afterwards, during the first semester of 2021, a new node of the university was established for the PEAMA Sumapaz in one of the rural schools of the district of Ciudad Bolívar in Bogotá. Finally, in the first semester of 2022, the newest version of the program was established in the rural sector of Torca, located almost at the city's northern border. In this case, 40 courses were offered for 18 students enrolled in 8 programs: civil engineering, mechanical engineering, mechatronics engineering, agronomic engineering, economics, linguistics, English philology, and French philology. Like all students of the PEAMA Sumapaz, the people that graduated from schools in Torca will remain in their place of origin while they complete the first semesters of their chosen programs. During this period, they will learn the foundational and part of the disciplinary content of their programs through project-based learning (PBL). Afterwards, they will go to the Bogotá campus of the UNAL as regular students.

Unlike the original version of the PEAMA, PEAMA Sumapaz is not entirely dependent on the university budget to run. Indeed, the Secretary of Education of Bogotá agreed with the UNAL to facilitate the access to higher education in the rural sectors of the metropolitan area of the city that they deemed most in need of the program. Thus, the funding for the PEAMA Sumapaz of the UNAL comes from an external entity.

The PBL model used in all iterations of the PEAMA Sumapaz promotes learning through participation in projects that can have concrete impacts in the communities of which students are part. Thus, in Nazareth, for instance, the participants of the project began their studies by deepening their knowledge of their place of origin and by identifying the potential of the region and its inhabitants (Cita Triana et al., 2020; Ordóñez-Ordóñez et al., 2020).

Given the enormous differences between the sectors where PEAMA Sumapaz was implemented, each PBL model used in the program has had to be developed almost from scratch. The form that the transdisciplinary PBL model will take is, thus, different according to the necessities, strengths, weaknesses, and potentials of the stakeholders of the community projects that will be used to teach students the skills that they will need to complete their programs of choice. This article describes the model used in the Torca version of the PEAMA Sumapaz and its first learning outcomes. In addition, some of the open-ended interviews with students carried out to assess the success of the program will be analysed.

2 Torca PBL model

Traditional PBL models use real and concrete problems as the starting point for learning. Problems that may be addressed or solved in a relatively short time are usually chosen for these models. Pioneering universities, such as McMaster in Canada, Maastricht in the Netherlands, New Castel in Australia, and Roskilde in Denmark, have researched and championed PBL models (Neame, 1989; Neufeld et al., 1974; Olsen & Pedersen, 2008; Schmidt, 1989). More recent and less widely spread variations of the PBL methodology choose long-winded projects rather than short problems to drive students to learn. Like many other models, the Aalborg University focus on this type of PBL (Kolmos et al., 2017). The PBL model implemented in Torca described in this paper is also based on project work.

The following statements were used as the PBL principles of the program:

1. Problems must be addressed and solved by a group.
2. Students are responsible for their own learning (self-directed learning).
3. The problems used for learning must be real problems.
4. The problems used for learning must be exemplary.
5. The solutions to these problems are inherently social and must be implemented with the aid of the community.

However, unlike traditional PBL practices (e.g. De Graaff & Kolmos, 2003; Savin-Baden & Major, 2004), the PEAMA students in Torca were comprised of people seeking different learning outcomes since not all of them enrolled on the same undergraduate programs. However, despite this heterogeneity, they were assigned the same problem and project. Thus, students of various engineering branches, the social sciences, and the

agricultural sciences worked side by side on a project that was important to the community to which all of them belonged. Since problems are rarely one-sided, the input from students of very different disciplines, far from hindering processes, often allows for developing more robust solutions.

The transdisciplinary model shown in Figure 1 presents the process followed by everyone involved in the project at Torca.

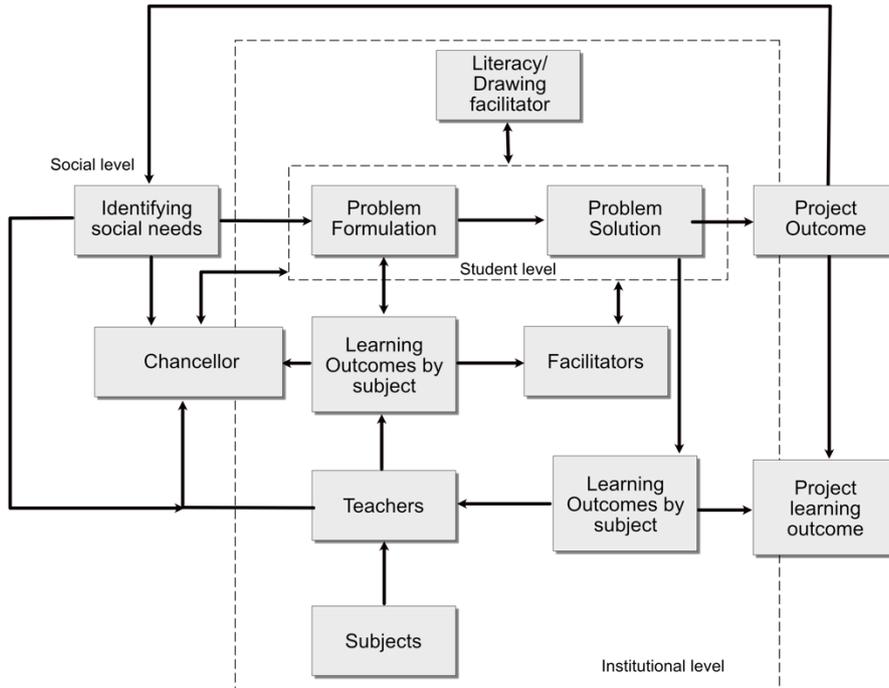


Figure 1. Torca PBL model.

This model works within a system of three interrelated layers: the social, the academic or institutional, and the student. The first layer is comprised of a community with multiple needs and problems that perhaps could be solved with the aid of higher-education students. The next layer includes the educational organisation and the people working to facilitate students' learning. Finally, students, in their learning process, are the core of formulating and solving the problem affecting the community.

Rather than focusing excessively on the idea of a teacher that transfers some ready-made knowledge to passive students, the role of teachers and other academic staff in the PBL implemented in Torca was to facilitate learning. Indeed, by making the concept of “educator” more flexible, four education-facilitation roles were created for the program. The first kind of facilitator resembles more or less a teacher of a subject in a regular classroom. These facilitators are responsible for concrete courses of the undergraduate programs that the students choose, but their most important task is to encourage students to come up with their answers. The second kind of facilitator is a transversal facilitator who supports the project according to planning, management, and group needs. In addition, they help in the development of soft teamwork skills. The third facilitator is the project chancellor, a person hired by the university to facilitate the exchange between the social and institutional layers. Moreover, the chancellor helps students, other facilitators, and the community to understand, on an academic level, the problems they will be working with. Furthermore, the chancellor works actively to keep the project on its track, i.e., they make sure that students do not get carried away by secondary problems while they work towards completing the project. Finally, the fourth kind of facilitator oversees bringing the literacy or drawing skills of the students to the levels necessary for them to successfully achieve the intended learning outcomes (ILOs) of their program of choice.

Naturally, even though the PBL method dictates that a common problem must be solved by all of the participants of the project, each study program has its own particular ILOs. Thus, to aid students in achieving the ILOs of the program that they chose, the general group of the Torca students was divided into smaller groups —according to the similarity of the contents and skills that they must learn— for some of the activities

that they partake in their day-to-day academic formation. Whether the students achieve these ILOs was determined on a case-by-case basis by a group of facilitators whose input weighed according to their involvement with each particular student. To do this, they assessed the material or immaterial artefacts produced by the students during the development of the project.

Given their importance to the whole process, all the relevant ILOs were explained to the students and the chancellor at the beginning of the project. This, on the one hand, served as a guideline for students during the problem-formulation stage of the project, and, on the other hand, allowed the chancellor to formulate his interpretation of the problems of the community in terms that would be useful for the students to develop the skills necessary for completing their programs.

The solution will produce a report with a material or immaterial product during the problem's development. For example, the product could be the specific outcome that students would use to learn in some or all subjects. In this case, each teacher involved must review the project to assess the achievement of the result of their matter. Consequently, they award the respective grade. On the other hand, the general project allows the evaluation of the transversal skills of the students.

Torca's model also uses subjects that are not part of the project due to their high content of propositional knowledge, such as basic mathematics, principles of chemistry, and computer programming. That cases have lectures and sessions with active learning.

3 Method

The students of the Torca experience went into three groups for the project work, considering that all the subjects involved in some projects to get more balance (Table 1). However, Philology and Linguistics had a group composed of 3 students for a need previously identified as relevant to these careers concerning the school radio station.

Table 1 Project groups for the Torca Model

Name	Curriculum	Project Theme
Student 1	Mechanical Engineering	Reactivation of a scholar greenhouse
Student 2	Civil Engineering	
Student 3	Civil Engineering	
Student 4	Economics	
Student 5	Mechatronic Engineering	
Student 6	Mechatronic Engineering	Solid waste management at the Nuevo Horizonte school
Student 7	Economics	
Student 8	Civil engineering	
Student 9	Agronomic Engineering	
Student 10	Mechanical Engineering	
Student 11	Mechanical Engineering	School Radio Station
Student 12	Philology and Language	
Student 13	Philology and Language	
Student 14	Linguistics	

Students analysed needs during the first six weeks of the project. Identifying the problem is essential that the problem address social needs, but not a pre-established solution.

After the first six weeks of model development, all of them, 14/14 students answered an open-ended interview by the project group. The interviews lasted around 45 minutes for the first two table groups and 21 minutes for the third group. The following research question: Have they found learning of the subjects during the formulation of the problem? Have they managed to identify the project work with the learning outcomes?

4 Results and discussion

The interviews were conducted in Spanish, transcribed verbatim, and analysed contextually. The PBL learning model has shown favourable results in student learning. However, they generally stated that they had difficulties formulating the problem.

During the formulation stage of the problem, the students have managed to understand concepts with the project tools on topic explanations given by the teachers. In this regard, one of the students stated:

"I believe that each subject gives us tools to be able to continue, and one no longer feels so lost concerning the first problem. It no longer feels like that. I don't know how to say it, like that emptiness, well, you can see, you can see a big difference. We picked up things more easily than before starting something before. It was like something. We were lost. So, they have given us excellent tools that are already helping us understand the things they, for example, explain". A Student translated from Spanish.

Despite achieving learning, there was significant difficulty defining the problem during the first six weeks of project work, representing about 40% of the time to carry out the project. The definition of the problem begins with the identification of the needs. Then students analyse it for a possible solution and the relevance to the learning results of the subjects and end with the declaration of research questions and objectives. From this analysis, teachers qualitatively observe if, with that analysis, the students will meet the ILOs by subject. That is the most crucial thing in the development of the project.

The most significant difficulties arose in formulating the objectives during the process. The learning model expected difficulties with problem identification and dilemmas to produce some transformative learning. Several reasons mainly explain it:

- The subject facilitators (Professors) promoted a solution that favoured the application of the theory of that subject, and that intention was generalised to all the group members.
- The Chancellor oriented the project toward the primary need identified.
- Students wanted to develop their solutions to the problem.

The different points of view of the teachers as facilitators caused a certain degree of uncertainty in the students. However, it would foster reflection and argumentation and recognise some topics' lack of depth learning.

"But it is that, for example, the tutoring. It is that they try to lead us along a path with a social stigma that does not bother us. It is as if we end up choosing that idea. Then another teacher comes with another idea, and we believe that idea. So, what happens is that we still don't have things very clear and well. After comes the other, by another side, that we had arrived. It is from one side to the other, and we get a little lost, and of course, since we don't understand things well, then on that side, it is as if they drag us to like their ideas and ideas." A Student translated from Spanish

Many different points of view in identifying the community's needs and how to approach the solution happened, but it seemed to favour a change in the ways students learn. When students come from environments where what the teacher says is done, finding several teachers saying such different things about the same thing produces uncertainty; this setting facilitates reflection (c.f. Rogers, 1951).

"If what Luis says is true, seeing too many points of view. Each one of them...As if he wants to direct us to his thinks or the place of his eyes. He makes us contradict ourselves. Perhaps, if not, we have changed the question." A Student translated from Spanish

This process took six weeks to work and not five as initially expected. However, there were times when the teachers also thought about the inefficiency and lack of clarity in the solution, encouraging behaviourist practices in them, as they manifested in several teacher meetings.

However, the students managed to move forward, understanding that a transformation in their way of thinking about one subject, from traditional teacher centred to student centred with PBL. Traditional local schools are behaviourist. In this regard, a student stated:

“That is called critical thinking, making a significant decision. That is why it makes it necessary, and that is why we have advanced so much. We put both decisions. For example, in each class, we change. Still, today we achieve that it will not modify. This situation occurs when the teacher tries to change the problem, but the students have learned to argue their point of view facing the problem.”
A Student translated from Spanish

Regarding the role of the reading, writing, and drawing facilitator, the students affirmed that they had received the support, and it has been helpful for the formulation of the problem. Reading and writing usually are difficult for students. However, Drawing is an engineering subject that often has an excessive workload in engineering programs. Nevertheless, the students seem to have connected with the other subjects. When asked about it, they stated:

“As we have been in the introduction, they have put us as terms, all those things, plates, plates that are worked freehand, plate in a cube, yes as the terms, as the line types.” A Student translated from Spanish.

The chancellor has been an element with a high degree of influence in the initial part of the project's development. However, his interventions with the students have caused conflict with the other teachers. The students stated there was a contradiction between what he said and the teachers, with a mistaken perception of disorganisation. According to the students' backgrounds, it is better to follow pre-established class schedules with well-defined projects, but not with the responsibility carried out by PBL.

“Well, we have the topic and the problem question. The subject from auditory pedagogical strategies, but we had it as inefficient- Then, talking with teacher Anonymous, he told us that the word insufficient was better. Insufficient auditory pedagogical approaches remained in the Torca institution. The situation is this. There are not enough auditory pedagogical strategies in the school that promote the participation of the members of the educational community, as well as the development of listening and speaking skills in students. Now on Thursday, we will have a class with a teacher who will define that well for us to see if we can leave it or change it for something else.” A Student translated from Spanish

As the previous text marks, at the beginning of the projects, the Chancellor proposed thematic solutions on details that the students did not take as a recommendation for reflection but as a suggestion that would later be transferred to the other facilitating teachers, causing conflicts between them.

5 Conclusion and perspectives

The article described Torca's transdisciplinary model and its first results in student learning outcomes during the problem formulation stage, showing that the model is viable and produces learning but needs minor adjustments. Since the model involving students, professors, facilitators, chancellor, and the community is transdisciplinary.

Although the students managed to define the problem and stated that they are learning, the formulation of the problem occurs in six weeks, which looks pretty long. It is mainly due to various disciplines and their concepts in identifying issues. Also, the need to link problems with ILOs caused some difficulties.

Difficulties incorporating many viewpoints seemed to foster students' critical thinking and argumentation. Finally, the students found a problem and its objectives that appropriately fit everyone to the subjects. However, until the end of the semester, they will show the deep of their learning.

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Are your rubrics hitting the mark? An exploration of the use of rubrics for project-based learning in engineering

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Abstract

Project-based learning is often introduced in engineering contexts to provide students with a better learning experience. Projects can be more authentic and can create opportunities for students to integrate knowledge and skills from several modules. Projects can also integrate an engineering curriculum with the simultaneous development and evaluation of technical and professional competencies. Furthermore, it is often argued that project-based assessments lead to deeper, more lifelong and self-directed learning. However, the assessment of work done during these projects presents many challenges. One of these challenges involves marking mechanisms. Project-based learning assessment frequently uses rubrics – designed to provide transparency regarding criteria used to evaluate students and consistency in the marking process. Sometimes, these rubrics can even be used as feedback to students. The questions arise, what makes a good rubric, and how should rubrics be designed to complement the intentions of project-based learning? This paper discusses findings from a qualitative study that explored lecturer and student experiences of assessment in an engineering school through interviews and focus groups. The study shows that the design of rubrics needs to be carefully considered to ensure that suitable types of learning are both encouraged and rewarded. Poorly constructed rubrics can result in dysfunctional student behaviours that do not support the intended learning outcomes of the assessment. This paper provides some practical recommendations that can be considered when setting up project-based learning assessments and designing assessment methods and rubrics to support these.

Keywords: Project-based learning; assessment; rubrics; student learning

1 Introduction

1.1 Background

In project-based learning, rubrics are often used as they are believed to be better suited to open-ended tasks that engage higher-order thinking (Jonsson & Svingby, 2007) and accreditation body outcomes and critical thinking (Newell, Dahm & Newell, 2002; Ralston & Bays, 2010). Furthermore, rubrics are often seen as a useful means to improve the efficiency of grading and providing feedback (Panadero & Jonsson, 2013). The purpose and function of rubrics vary, including clear expectations and transparency regarding the assessment and grading process, feedback, and self-evaluation skills. Regardless of the intention, rubrics are intricately woven into the grading or marks that students receive, and as a result, the power and influence that these rubrics have in the learning process are unquestionable (Boud, 2007). While rubrics can be carefully designed, how students respond is a function of how rubrics are perceived and engaged with (Lindberg-Sand & Olsson, 2008). If project-based learning is to affect the positive and sustainable change in student learning that is intended, a thorough understanding of what influences student assessment decision-making is required (Prosser & Trigwell, 1999).

1.2 Purpose of this study

The original study from which this paper draws its findings was designed to understand how assessment was designed and perceived by students in an Engineering School where student performance was significantly lower than desired. The larger triangulated study drew on student surveys (Hattingh, Dison & Woollacott, 2019), lecturer interviews (Hattingh & Dison, 2019) and student focus groups (Hattingh & Dison, 2021) to answer the following over-arching research question: How might current assessment practices be transformed to improve the quality of student learning in the School? The study adopts a theoretical lens that draws on learning-oriented assessment (Carless, 2015) and sustainable assessment (Boud, 2007). The intention is to

explore how student engagement, performance and success can be positively influenced by adapting assessment approaches that focus on the learning that is taking place and prepares students for their own future learning needs.

Many of the findings from the original study referred to rubrics, mainly used for projects, and how these were designed and used by lecturers and perceived and engaged with by students. The purpose of this paper is, therefore, to draw on the specific findings around rubrics to explore how rubric design can influence student learning and, through this, make recommendations for rubric design to support the overall learning intentions of project-based learning.

2 Literature review

2.1 Purpose of rubrics

Traditionally, the purpose of a rubric is to assign a level of performance or a grade (Goldberg, 2014) or "guide the analysis of the products or processes of students' efforts" (Moskal & Leydens, 2000). This is known as the summative purpose of a rubric. When used for a summative purpose, much focus is on the quality of assessment grading (Panadero & Jonsson, 2013), considering reliability and validity of the rubric itself, inter- and intra-rater reliability (Moskal & Leydens, 2000) or how accurately a score can reflect a student's abilities (Newell et al., 2002).

A formative approach to rubric use considers alignment with course objectives, clarifying expectations to students (Newell et al., 2002), and providing feedback (Catete, Snider & Barnes, 2016). Rubrics can also be used to provide a quick overview of student progress (Ralston & Bays, 2010) which can be used to adapt the learning environment.

Rubrics, if effectively designed, can be used both summatively and formatively (Stegeman, Barendsen & Smetsers, 2016). They should articulate expectations for an assessment task and typically do this through criteria and descriptions of levels of quality in relation to each criterion (Reddy & Andrade, 2010). Rubrics in more design or project-oriented contexts can include criteria that consider design process elements such as problem definition and feasibility, product-oriented criteria such as user experience and professional competencies such as teamwork and entrepreneurship (Huang & Jong, 2020).

2.2 Impact of rubrics on student learning

Rubrics can positively influence student learning in several ways. Rubrics are a mechanism to make assessment criteria explicit which provides transparency to students, but it also requires lecturers to reflect on these criteria when setting up assessment tasks. In this way, rubrics can facilitate constructive alignment (Biggs, 1996) of assessment design which supports improved student learning. Rubrics can increase transparency, reduce anxiety and provide feedback to students (Panadero & Jonsson, 2013). For this feedback to be valuable, students need to identify what good performance is, how their own performance relates to this and how they can go about closing the gap (Stegeman et al., 2016), promoting sustainable assessment practices (Boud & Soler, 2016). All of this supports the development of self-regulation skills and self-efficacy (Panadero & Jonsson, 2013). Rubrics are further able to support self-assessment (Andrade & Valcheva, 1999) and related activities such as peer evaluation (Mullen, 2003) which can support the development of lifelong or sustainable learning skills (Boud & Soler, 2016).

2.3 Challenges of rubrics

There are, however, many challenges with rubric design. Some of these stem from rubrics that are not well designed or designed with a predominantly summative focus. Others originate from a lecturer-focused approach that does not consider how students will engage with and respond to the rubrics and the impact that this will have on their overall learning experience.

The criteria of many rubrics focus on the product or artefact that is being assessed (Catete et al., 2016; Verleger, Rodgers & Diefes-Dux, 2016), which can mean that there is limited consideration, visibility or evaluation of the

process that is taking place and the assessment task remains product-centred (Gibbs, 1995). While it is often easier to grade or evaluate something tangible such as a design or a design report, it is the process that students will take with them into the working world. If rubrics are to be used to provide formative feedback to students, the criteria and descriptors also need to provide guidance on how the process that leads to the artefact can be improved in the future. If rubrics are to be used to develop self-evaluation capacity, students need this visibility to judge their approaches.

Criteria in rubrics often include scale descriptors such as adequate, reasonable or poor (Huang & Jong, 2020), clear, accurate, complete and fair (Ralston & Bays, 2010) or few, some, most, all, slightly, moderately, mainly and extremely (Tierney & Simon, 2004). While these may enable raters to be more consistent and reliable, one may question how useful these descriptors are to a student and whether they enable valuable feedback that students can engage with and improve. While a grader may be able to develop a sense of what complete or reasonable is, students need to develop these skills. In some cases, examples can be included in the descriptors, often to improve reliability and validity or grading, but also to try and provide better guidance to students. Depending on student dispositions and intentions when using the rubric, this can tempt students to adopt procedural or tick-boxing approaches, defeating the rubric's objective to develop self-evaluation skills.

Whenever using rubrics, it remains key to consider how the students will perceive and use the rubrics during the design process. By providing clear expectations and criteria, rubrics provide a very structured framework that students can use when tackling assessment tasks. Some would argue that students could become dependent on these rubrics. The clear guidelines could lead students to avoid a trial-and-error approach to their problem-solving processes (Panadero & Jonsson, 2013), following a more mechanistic procedural-learning approach (Case & Marshall, 2004). This does mean that rubrics can encourage instrumentalism or assessment as learning where criteria-compliance dominates the learning process (Torrance, 2007), which works against the idea of project-based and sustainable assessment practices.

2.4 Opportunities for consideration

The value of rubrics often remains centred on the robustness and inter or intra-rater reliability. Rubric design principles tend to speak to inconsistencies and redundancy in descriptors, unevenness in increments and limited routes to partial credit (Goldberg, 2014), language, terminology and phrasing (Stegeman et al., 2016) and frequency and intensity of descriptor levels (Tierney & Simon, 2004). Even when rubrics are designed to provide feedback, analysis of the rubric often remains focused on reliability and validity and how the feedback is perceived and used by students is not evaluated (Catete et al., 2016; Stegeman et al., 2016). While sophisticated rubrics provide a structure that can be used to provide a holistic and accurate evaluation that extends beyond the product or artefact to critical thinking (Ralston & Bays, 2010), very rarely do the studies discuss how the rubrics are perceived or used by students.

Panadero & Jonsson (2013) conducted a review of literature that explores the impact of rubrics on student learning. Their findings revealed that most research remains focused on the summative aspect of rubrics and limited studies consider the formative impact of rubrics. For those studies that do look at the formative aspect, few have been conclusive as case studies that use rubrics formatively typically combine rubric use with other meta-cognitive activities such as peer-evaluation.

While the value and importance of the summative aspect of rubrics are acknowledged, their influence on student learning behaviours and, ultimately, student learning cannot be ignored. Learning-oriented and sustainable assessment thinking requires that the primary purpose of any assessment activity is the support of student learning and the development of self-judgement and evaluation skills. Since rubrics form an integral part of this process in project-based learning, it is imperative to understand how rubrics can be designed to support this.

3 Method

3.1 Study context

This study takes place at an engineering school ('the School') in a South African university. Assignments (or projects), tests, and exams are the primary means of assessing student performance. Larger projects are used in various courses but mainly in design courses and can be conducted individually or in groups. Although the predominant means of assessing remains tests and exams, there has been a distinct shift toward the use of projects. Projects can contribute significantly to the overall course mark in practical and design courses.

3.2 Research approach

The findings presented in this paper draw from two parts of a larger triangulated case study. The original study consisted of a student survey, lecturer interviews and student focus groups to obtain a holistic view of assessment practices and how these influence student learning behaviours. The study used a qualitative exploratory approach to draw on individual and group experiences. This paper will draw specifically on findings from the lecturer interviews and student focus groups. The study aims to understand the decision-making and intentions of lecturers when designing and using rubrics and the students' experiences and intentions when tackling assessment tasks that use rubrics. The study does not focus on a particular module but considers students' holistic approach to assessment tasks since the orientation of a student towards assessment is influenced by their prior learning experiences (Biggs & Tang, 2011) and what happens in a particular course and around it (Boud & Soler, 2016).

3.3 Lecturer interviews data collection

Semi-structured, individual interviews were conducted with ten purposively sampled lecturers in the School. Lecturers were posed with a series of open-ended questions designed to explore their perceptions and experiences of the overall purpose of assessment. These included factors that influence the design of assessment tasks; explicit and implicit criteria used to design and evaluate tasks; communication of expectations and criteria to students, feedback, experiences of student engagement with tasks, how well assessments evaluate the intended outcomes and how assessment could be improved. The interviewed lecturers teach a range of courses across all four years of study, including mechanics, engineering drawing, mechatronics, engineering design and laboratory courses and complementary courses such as business management.

3.4 Student focus groups data collection

Focus groups were conducted using a protocol that encouraged students to reflect on both their own experiences and, where necessary, to comment on what other students might experience or do (Merriam, 2009). The questions probed several issues, including students' overall approach to their studies in respect of different assessment tasks; how they knew what was expected from them in assessments; an example of a situation in which they were disappointed by an assessment, and how they reflected on this experience; forms of received feedback, and their response to feedback. Students were asked to reflect individually by writing down their thoughts on selected questions before engaging in the group discussion, allowing them to formulate their thoughts before being influenced by others (Gibbs, 2007). The focus groups were facilitated by the researcher and observed by a research assistant. The sessions were recorded and later transcribed.

The focus groups sampled all students in the School from the second, third, and final years of study. Four separate groups of students were chosen for the focus groups using maximum variation sampling (Cohen, Manion & Morrison, 2011): a mid-performing group (FG1), a high-performing group (FG2), a low-performing group (FG3) and a group of students categorized as turnaround students (FG4). The turnaround students performed exceptionally poorly in one year, followed by a year when they performed particularly well. Emails were sent to students from all groups, inviting them to be part of the focus group on a specified day. The number of emails sent out was increased until five to ten students (Merriam, 2009; Cresswell, 2012) consented to be part of each focus group. A total of 22 students participated in the focus groups.

3.5 Data Analysis

Recordings of the interviews and focus groups were transcribed and analysed. Focus group analysis included individual voices, and the sense-making that emerged as a shared understanding was developed in the group (Cresswell, 2012; Wilkinson, 2004). The original study tracked emerging concepts using a coding system linked to key supporting quotes (or evidence). This process was repeated for each transcript, comparing and adding codes when required. The identified codes and evidence were then captured into a case study database (Yin, 2014). A comparative analysis was then carried out, clustered into topical categories informed by the literature (Merriam, 2009) until a set of emergent themes was obtained. To address the credibility of the findings, rich descriptions and evidence were used to support the claims. Surprising or 'outlying' evidence was investigated, and rival explanations were considered when interpreting data by referring to literature and using peer review with two colleagues (Cohen et al., 2011; Merriam, 2009). For this paper, themes and codes that linked specifically to the topic of rubrics were extracted and are discussed herein.

4 Findings and discussion

4.1 Introduction to the findings

Although there are indications that assessment is sometimes used as a learning opportunity, the predominant thinking in the School is assessment of learning, to evaluate the competence of students. This thinking frames most decisions that lecturers make when designing and using assessments. Lecturers aim to discourage the use of rote learning strategies and attempt to test if students have a deep understanding of concepts by requiring students to apply their knowledge and understanding of concepts to new and unseen problems, often using real-world scenarios. Students indicate a preference for projects as they enable them to better understand concepts and are more relevant to the real world and the engineering profession. Student learning behaviours in the School are, however, dominated by a studying for passing paradigm where students strategically make decisions that will enable them to pass or obtain as many marks as possible, often at the expense of learning. Within this context, findings of particular interest to the topic of rubrics are discussed. The quotations are referenced back to the data source, i.e., L1 representing lecturer 1 and FG1 representing focus group 1.

4.2 Product or output-focused nature

Lecturers describe an underlying set of skills that students are expected to exhibit. These align with the process of problem-solving and include: to understand and visualise complex problems, to source and understand relevant information, to apply appropriate concepts to analyse/solve complex problems, to integrate the problem into related systems and to communicate ideas. However, many lecturers describe the criteria used to evaluate students in terms of the specific requirements that the product that was being designed needed to meet or sections of a report rather than the outcomes that the student needed to demonstrate to be able to design the product so that the product met the requirements. Rubrics reflect this and are often designed in a way that provides criteria simply as mark allocations for each section of a report or task. Gibbs (1995) warns against using rubrics in a way that does not provide any indication of the quality of work that is required to achieve the marks that are allocated for a particular section. Furthermore, as the assessment criteria are product-oriented, they understate what students need to achieve and provide minimal scaffolding for students to appreciate the concept of quality in their work (Sadler, 2010). Feedback also typically focuses on the product of the assessment task, indicating how the answer or design has not met the engineering specifications or requirements without suggesting what the student could have done differently to improve the quality of their engagement with the task to deliver a quality final product. The feedback is, therefore typically aligned to "what" needs to be improved, a focus on the diagnostic element, and not the "how" of getting there, the bridging-the-gap element (Boud & Molloy, 2013). This simplistic view of criteria used in the rubrics disregards the process of learning and engagement, which affects feedback and student use of rubrics, including the development of judging capabilities and self-evaluative expertise (Carless, 2015).

The breaking down of criteria into discrete elements or steps is perceived to ensure consistency and objectivity in marking. However, the criteria that assess quality or understanding underpinning the steps become much more difficult for lecturers to explain. Some lecturers admit that they find it difficult to explain to students what is required of them to perform well:

"Students often ask: ...how can I pass this course? And even though I get asked this a lot of times, I always struggle to answer it....have you understood and can your design, do what it needs to do?" (L9)

This inability of some lecturers to explain to students **how** to improve could stem from a lack of awareness of the importance of threshold or bottleneck concepts and their role in unlocking understanding and the construction of knowledge and ideas (Middendorf & Pace, 2004). As a result, rubric criteria and therefore, feedback does not articulate to students what they need to demonstrate to meet the required outcomes, which further hampers the development of self-evaluative skills.

4.3 Tick-boxing and instrumentalism

To facilitate a shift to learning-oriented and sustainable assessment, attempts need to be made to develop students' capacity to self-evaluate. This can be done in several ways, but improving the communication of expectations and criteria to students is a key priority. However, as students are already operating in a studying for passing paradigm, there is a risk that increasing the transparency of outcomes and criteria could lead to an over-reliance on these with criteria compliance (Torrance, 2007) replacing learning. As the content of rubrics remains product rather than process-centred, this can lead students to use the rubrics as a means of cue-seeking and mark-hunting, resulting in mechanistic and "tick-boxing" strategies. This lecturer reflects:

"So I almost think that the very detailed rubric can be a disadvantage. Because they're just trying to tick boxes at the end of the day." (L1)

Although assignments and projects are seen as a better way of encouraging students to develop the necessary process-type skills, the use of rubrics in this School is potentially encouraging students to go through the breakdown, ticking off steps in a procedural manner in order to "get marks". This is certainly exacerbated by the already existing student focus on marks in the School, where students appear to prioritise and focus their attention based on the marks that are provided for all assessment tasks:

"that's why the interactions that you end up kind of having with the lecturers are okay, why are my marks so low...it's not okay, help me understand this concept, it's my mark needs to advance...so at the end of the day, it's all about marks." (FG2)

Students particularly do not see value in feedback for an assignment if they are not going to get something similar again since the rubric is only used to "tick boxes" against mark allocations rather than change learning behaviours and approaches to solving problems that are universally useful in future learning.

"Like also in the rubric, it's not always helpful, because some of the lecturers only give it to you when (you've already done the work) and that doesn't help you because then you're kind of just doing whatever and when you get the rubric you might have to add something in or take out or stuff. So if they give it to you beforehand you then know like how to use your time." (FG1)

"I think getting a rubric also helps. Especially if there'll be a follow or similar type thing, then you can see exactly where the marks are, where you need to improve." (FG2)

The product-centred structure of rubrics and tick-boxing approach of students can also lead to mechanistic or boxing approaches to tackling assignments:

"...the students have a mechanistic approach ...{without} the subtleties as to why you should be doing this or that." (L8)

This can also be amplified by group projects:

"Students end up splitting parts of a report (between group members). And this is a problem, not only because you're not actually practising but also because then you're not realising what the link is between everything. And if you're having to do the entire project that becomes an entirely different story." (L7)

The adoption of mechanistic approaches implies a lack of underlying problem-solving skills and strategies and the development of skills that can integrate elements. This can exist between aspects of an assignment, sections of reports, problems and surrounding systems and how courses and the degree links together as a whole.

4.4 Agency and self-evaluation

Findings from this study reveal that students are not necessarily developing self-evaluative skills and do not adopt agency for their own learning. There is a sense that the agency for learning and assessing lies with lecturers, impeding the ability of students to develop their technical and professional competencies. Students' ability to self-evaluate and improve is limited by the current product-centred nature of rubrics which do not enable students to see where they are going wrong or develop ways of reflecting, changing and improving. The following participant sums up this frustration:

"You work really hard on your assignment and you get it back and you realise you've gone wrong, and it gets you really down because you spent so much time doing it and it doesn't show you what's wrong." (FG1)

This quote also hints at a lack of agency. It appears that students expect lecturers to "tell them what is wrong" rather than developing the ability to self-evaluate where they went wrong.

"...lecturers should sit and see where most students are going wrong and try to come to class and work out some of those mistakes that students make." (FG1)

This is confirmed by lecturers who also discuss their frustrations:

"That is the number one question students always ask is what are you expecting? Where's the rubric? Is this right?...Their biggest question is, how will I be assessed? Is this work good enough? Have I done enough?" (L4)

The development of self-evaluative skills is a crucial aspect of sustainable assessment and project-based learning. However, the assessment context needs to provide structure and support for students to identify with, adopt and exercise agency to create opportunities for developing these skills (Ritchie, 2016).

5 Conclusion

The findings show that rubrics can indeed influence student learning behaviours. Furthermore, they show that they can have a negative impact on the competencies that project-based learning aims to develop. As a result, rubrics should be intentionally and carefully designed, and the perception and response of students should be investigated. Practically, rubrics should incorporate criteria and descriptors that are process-centred and encourage students to integrate their learning in other projects and courses to develop sustainable, lifelong learning skills. They should provide sufficient guidance for students to develop self-judgement skills without becoming over-reliant. It is also recommended that the use of rubrics includes supplementary meta-cognitive activities that transfer agency and scaffold the development of relevant skills. This requires lecturers to think beyond the reliability and validity of rubrics, considering the student learning process, threshold concepts and constructive alignment.

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Proposal of Method for Risk Assessment of Project-Based Learning Failure via AHP and BBN – A Case Study

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Abstract

Project-based learning has been used in engineering education because it is expected to develop students' professional knowledge. Project-based learning research and practices in engineering education are growing. The author conducted in-depth literature research to identify the risk factors in PBL application and observed that risk assessment in implementing the PBL via Analytical Hierarchy Process and Bayesian Belief Networks had not been addressed. The study aims to propose a method to identify the risks of using the Project-Based Learning method and involving companies when teaching engineering disciplines to engineering students. A Case Study was conducted on the application of PBL to support local companies in a specific region. The risks were identified, a relationship digraph was used to identify the categories of risks, a survey was conducted to elicit risk probabilities, AHP was used to estimate risk impact, the global risk scores were estimated, and the responses to the risks were defined. BBN was also used to combine the probabilities of risks and perform sensitivity analysis. Future research directions for engineering education researchers are proposed to optimize Project-based learning curriculum design. The study provides a method to be used by professors, students, and decision-makers to identify risk factors that can impact the quality of teaching in engineering education and implement proper risk responses to the risks. The contribution is significant since it improves the quality of universities.

Keywords: Active Learning; Engineering Education; PBL; Risk Assessment, BBN, AHP

1 Introduction

Student-centered teaching methods by 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. It has been noticed that current literature on the Use of PBL in engineering education has not addressed the risks of PBL failure, and even less attention has been paid to risk responses to ensure excellence in projects. In this study, the author conducted a literature review to identify and list key risk factors when implementing PBL in engineering education. Being aware 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 using Analytical Hierarchy Process (AHP) and Bayesian Belief Networks (BBN) to identify the risks and responses to ensure successful PBLs are conducted in collaboration with local companies. If risk factors are not identified, and proper responses are not provided PBL project can fail. 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 teaching engineering students. The diversity of risk factors presented here highlights the complexity of implementing 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 PBL. It is noteworthy here that the study focuses on project-based learning involving companies. Successful PBLs, in this case, will result in a significant reduction of business risks and achievement of excellence in quality and organizational safety. None of the studies present herein dealt with risk assessment and its impacts on PBL. The literature revealed that most previous studies addressed PBL and challenges without giving a methodology for risk prioritization using AHP (Analytical Hierarchy Process) and Bayesian Belief Networks.

The paper responds to the following research questions:

Research Question 1: What are the most significant risk factors for using PBL in collaboration with local companies when teaching engineering students?

Research Question 2: What are the probability and the impact of these risks and the global risk scores?

Research Question 3: What are the responses to high RPN risks, and how to combine the risks and conduct a sensitivity analysis?

This paper is divided into five sections; the first introduces the concepts of the study, the second describes PBL, the challenges and Risk Assessment of PBL Failure, BBN (Bayesian Belief Network), AHP (Analytical Hierarchy Process), and Section 3 describes the Methodology, section 4 results, and section 5 concludes.

2 Project-Based Learning

Previous significant studies about PBL Methodology and Challenges in its implementation are presented in subsections 2.1 and 2. 2.

2.1 Design of PBL Method

Previous significant studies about PBL are presented herein. Moliner et al. (2019) developed a work focused on describing the experience of using PBL methodology in Materials Science courses conducted by four different 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 the implementation of PBL, specifically on the opportunities and challenges. The students choose their topic, identify it, explain why they choose it and solve the problem. Thevathayan (2018) presented an experience evolving a hybrid-teaching model by using the action research cycle plan-act-observe-reflect over three semesters. The main novelty of the approach was the use of 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 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 of 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 PBL offering in engineering PBL at Griffith University in Australia. The author observed that students generally 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 models. In particular, the process deals with the definition of 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 Methodology 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 team up students, how to proceed with planning, how to swap planning outputs among teams, and how to implement a Project.

2.2 Challenges and Risk Assessment of PBL Failure

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 lack of teacher teams leads to one teacher acting as both examiner and PM. 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 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 the implementation of 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 BBN (Bayesian Belief Network)

BBN has been widely used to estimate corrosion risks (Yang et al., 2016). Bayesian Network Networks were used to ease knowledge acquisition of causal dependence in CREAM (Ashrafi et al., 2016). The Bayesian variable was used in the selection to analyze regular resolution IV two-level fractional factorial designs (Chipman et al., 2016). BBN's is a causal structure used by probability risk analysis specialists to obtain information about important risk events and the necessary interventions to address risks (Rechenthin, 2004; Mosleh, 1992). The Use of BBN's in safety, maintenance, and reliability has increased quickly (Mahadevan, 2001). Bayesian methods have been used comprehensively in many applications and provide a structure for addressing the limitations of human reliability analysis (Podofilini and Dang, 2013; Mosleh and Apostolakis, 1986; Droguett et al., 2004; Groth and Swiler, 2013). None of the above previous studies deals with the application of BBN to the Risk Assessment of Project-Based Learning Failure. The objective of the BBN methodology is to allow more straightforward predictions of risk events and also execution of sensitivity analysis; it is a structure representing arguments when uncertainty exists.

2.4 AHP (Analytical Hierarchy Process)

Saaty (1980) was the first to use AHP as a decision-making tool to provide the relative weight of criteria based on a hierarchy structure. The author proposed the use of pairwise comparison to evaluate alternatives. The method has been used extensively to solve complex decision problems. It divides a problematic issue into smaller parts aiming at ranking them hierarchically. Thus, the relative importance of alternatives is weighed accordingly. In this paper, AHP is utilized to consider/prioritize the key risks affecting the PBL result. The AHP is an excellent tool to provide weight for the different risk levels; the first phase is to create a pairwise evaluation matrix (A), as introduced by (Saaty 1980), by utilizing the relative importance scale. The matrix A represents a pairwise evaluation matrix where each element "a_{ij}" (i, j = 1, 2, ..., n) represents the proportional importance of two compared elements (i and j). The higher the value, the stronger the first element preference(i) over the second (j). (MIs and Otcenaskova, 2013).

3 Methodology

The research was conducted in Google Scholar, Scielo, Scopus, and Web of Knowledge using the keywords: Active Learning; Engineering Education; PBL; Risk Assessment, BBN, and AHP. The following Journals related to engineering education listed in JCR Journal Citation Reports Full Journal List were also reviewed for state-of-the-art papers on the subject: 1 – International journal of engineering education – Ireland; 2 - Journal of

engineering education – USA; 3 - Journal of professional issues in engineering education and practice – USA; 4 - Computer applications in engineering education – USA; 5 - International journal of electrical engineering education – England; 6 - European journal of engineering education. 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 following keywords were used: Active Learning; Engineering Education; PBL; Risk Assessment, BBN, AHP. The searched papers were reviewed by reading the abstract and introduction; those relevant to the research objectives were selected. In this project, 50 research papers were selected among 120 to identify risk factors in the PBL use and implementation. The papers covering problem-based learning and not covering the Design of PBL and challenges/risk assessment of PBL failure were disregarded.

A survey was conducted as a case study. The study adopted the approach of building theory from Case Study Research (Eisenhardt, 1898) and Kin (1999). It combined data from archives, interviews, and observations and focused on the application of PBL by a university in partnership with a company. A PBL process map was constructed, and a list of risk factors found in the researched literature and in the process map was then 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 survey in Google forms was created to obtain the probability of students, professors, and organization leaders' risk factors. Students, professors, and professionals from a local university and its major partner company completed the survey in 2022. It was responded to by approximately 12 participants, who were asked to estimate the probability that a given risk could cause the failure of a PBL project. AHP (Analytical Hierarchy Process) was used to find the relative importance (impact) level of the risk categories. The global risk scores (combination of probability and impact scores) were obtained by multiplying the probabilities and impact scores. The next step was implementing risk responses to address the risk categories (Risk Priority Number). The last step was preparing the BBN and performing sensitivity analysis to identify the risks with a higher impact on the PBL failure. The steps of the Methodology are shown in Figure 1.

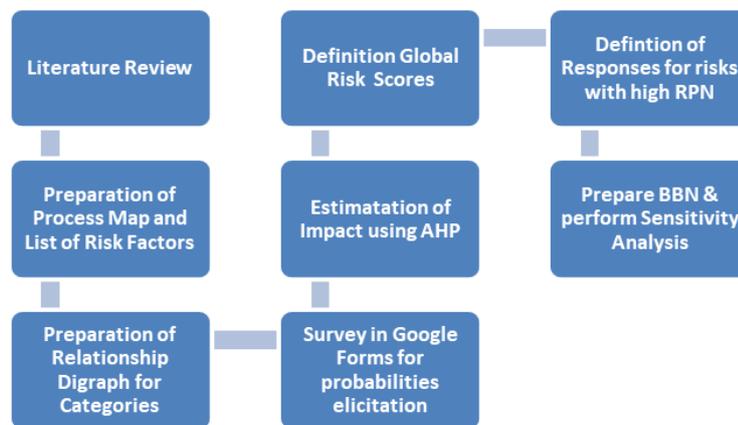


Figure 1. Methodology flowchart

4 Results

This section shows the process map, the list of risk factors impacting PBL failure, the AHP for the Technical Learning principle, the list of probability and impact scores, the BBN combining all risk factors, and the tornado chart resulting from sensitivity analysis. 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. An AHP matrix was prepared for each Learning principle to obtain the risk factor's impact values. The probability values for risk factors were obtained with the survey. The probability and the impact values for each risk factor were combined to obtain the risk index. The risk index was color-coded as per the risk index value. Finally, a BBN was also used to identify the most significant risks impacting PBL projects using sensitivity analysis.

The flowchart in Figure 2. shows the process map used by universities in conjunction with partner companies in PBL projects and the risks presented in each step. The letters in red represent the category of risks: C: Cognitive Learning Failure, S: Social Learning Failure, and T: Theory and Practice Learning.



Figure 2. Structure in the conduction of 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 PBL process
		C2	Students and professors not appropriately trained on the PBL procedure
		C3	Lack of standard work for the execution of PBL's
	CB: PBL specific requirements not defined accurately	C4	Poor explanation of expectations to students
		C5	Lack of background definition on principle behind projects
		C6	No clear definition of requirements
		C7	Project complexity incompatible with time and resources
	CC: Wrong Choice of Project	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	Number of Students in project inadequate (too big or too small)
		S2	Project team members not equally strong
		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 not active in the project
		S8	No focus on the project
		S9	Relationship professor and student not good
		S10	Students and Professor 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 probabilities for each risk factor were elicited from students and professors using a Google Form survey. AHP was utilized to compare the risk factors in each learning principle category pairwise. An interview process was conducted to obtain from professors and students the degree of impact of each risk on the failure of PBL. The risk weight values (impact) were quantitatively calculated based on the completed pairwise comparative matrix. The empirical data was converted into mathematical models using a hierarchy table established by Saaty (2009). The relative importance of the risks is translated into the numerical pairwise comparison matrix shown in Table 2.

Table 2. Hierarchy table

Importance	Definition
1	Both elements are of equal importance
3	Moderate importance of one element compared to the other
5	Strong importance of one element compared to the other
7	Very strong importance of one element compared to the other
9	The extreme importance of one element over the other

AHP was utilized to obtain the impact for each risk and respective risk category. A pairwise comparative matrix was prepared, as shown in Table 3, for the Technical Learning principle, and similar tables were prepared for the other principles. An interview process was conducted to obtain from 3 professors and 6 students the degree of impact of each risk on the failure of PBL.

Table 3. AHP for the Technical Learning principle

Criteria Comparison Matrix										
<i>Risk Factors</i>	CA: No Standardization of PBL Procedure	CB: PBL specific requirements not defined	CC: Wrong Choice of Project	SA: Team Building practices not used	SB: PBL Professor not active in the project	SC: Team lack of Motivation	TA: PBL Professor not prepared for the project	TB: No definition of PBL records organization	TC: Students not prepared for the PBL	Weights
CA: No Standardization of PBL Procedure	1	1	7	5	3	7	3	5	3	0,26
CB: PBL specific requirements not defined accurately	1	1	3	5	3	7	3	7	3	0,23
CC: Wrong Choice of Project	1/7	1/3	1	1	5	3	3	3	3	0,13
SA: Team Building practices not used	1/5	1/5	1	1	1	1	1/3	3	3	0,07
SB: PBL Professor not active in the project	1/3	1/3	1/5	1	1	3	1	3	3	0,08
SC: Team lack of Motivation	1/7	1/7	1/3	1	1/3	1	1	3	1/3	0,04
TA: PBL Professor not prepared for the project	1/3	1/3	1/3	3	1	1	1	5	3	0,10
TB: No definition of PBL records organization	1/5	1/7	1/3	1/3	1/3	1/3	1/5	1	1/3	0,03
TC: Students not prepared for the PBL	1/3	1/3	1/3	1/3	1/3	3	1/3	3	1	0,06
TOTAL	3,69	3,82	13,53	17,67	15,00	26,33	12,87	33,00	19,67	

The impact scores shown in Table 3 were color-coded using Table 4.

Table 4. AHP

Impact Level Score		
Score	Impact Level	Impact
5	High	More than 0,16
4	Elevated	0,12-0,16
3	Moderated	0,08-0,11
2	Low	0,04-0,07
1	Limited	Less than 0,04

The final risk index for each risk factor was obtained in the following way. As an example, considering Table 6 (applicable to Theory and Practice Learning Failure), the probability for T1 is 0.7, and the impact is 0.05; based on Table 5, the probability rating score is (value: 4). The impact rating score is (value: 2) for the risk factor T1. Figure 2 is referenced to obtain the final risk index for T1. In this case, the final score is (value: 8), the product of 4 by 2. The risk index for the other Principles is calculated similarly.

Table 5. Probability and Impact Score.

Probability Level Score			Impact Level Score		
Score	Probability Level	Probability	Score	Impact Level	Impact
5	Expected	More than 0,80	5	High	More than 0,16
4	Very probable	0,51-0,80	4	Elevated	0,12-0,16
3	Probable	0,31-0,50	3	Moderated	0,08-0,11
2	Improbable	0,11-0,30	2	Low	0,04-0,07
1	Almost no probability	Less than 0,10	1	Limited	Less than 0,04

The global risk score (index) was determined using the risk scoring matrix shown in Figure 2 (Hyun et al., 2015). The final risk index is obtained by combining the probability and impact.

		RISK						
		Limited	Low	Moderate	Elevated	High		
		1	2	3	4	5		
Probability	Almost no probability	1	1	2	3	4	5	
	Unlikely	2	2	4	6	8	10	
	Probable	3	3	6	9	12	15	
	Very probable	4	4	8	12	16	20	
	Expected	5	5	10	15	20	25	
Risk Factor Classification								
1-5		Insignificant	6-9	Tolerable	10-16	Undesireble	17-25	Intolerable

Figure 2. Final Risk Index

The global risk score (index) for Cognitive Learning Failure, Social Learning Failure was determined using the same process.

Table 6. Probability and Impact Score Theory and Practice Learning Failure

Factors	Probability	Impact	Probability Score	Impact Score	Risk Index
T1 - Professor do not support knowledge base construction	0,7	0,05	4	2	8
T2 - Professor do not support Argument base construction	0,7	0,0404	4	2	8
T3 - Lack of professor technical content knowledge and experience	0,5	0,2401	3	5	15
T4 - Professor has no industrial skills	0,6	0,2189	4	5	20
T5 - Lack of definition for the project content organization	0,7	0,0457	4	2	8
T6 - No definition of report content	0,8	0,026	5	1	5
T7 - Problem solving methods not defined	0,6	0,1075	4	3	12
T8 - Students are not familiar with specific process theory behind PBL	0,2	0,0935	2	3	6
T9 - Students have no knowledge of Quality Tools for problem solving	0,5	0,1102	3	3	9
T10 - Students not trained on specific PBL industrial process	0,3	0,0666	2	2	4

The authors weighted the probability values obtained with the survey based on the respondents' experience, as shown in Table 7. The probabilities were then loaded into BBN software, and the probabilities of each risk were combined, allowing sensitivity analysis to define the most significant risk factor.

Table 7. Experience Period (E) & Weight

Experience Period (E) & Weight	
Less than 5 years	0.60
6-10 years	0.75
11-15 years	0.09
More than 15 years	1.00

The probabilities were loaded into BBN software. BBN was used because the statistical causal structure was key to obtaining information about risk events to mitigate them. Charts in Figures 3 and 4 could be generated using the software.

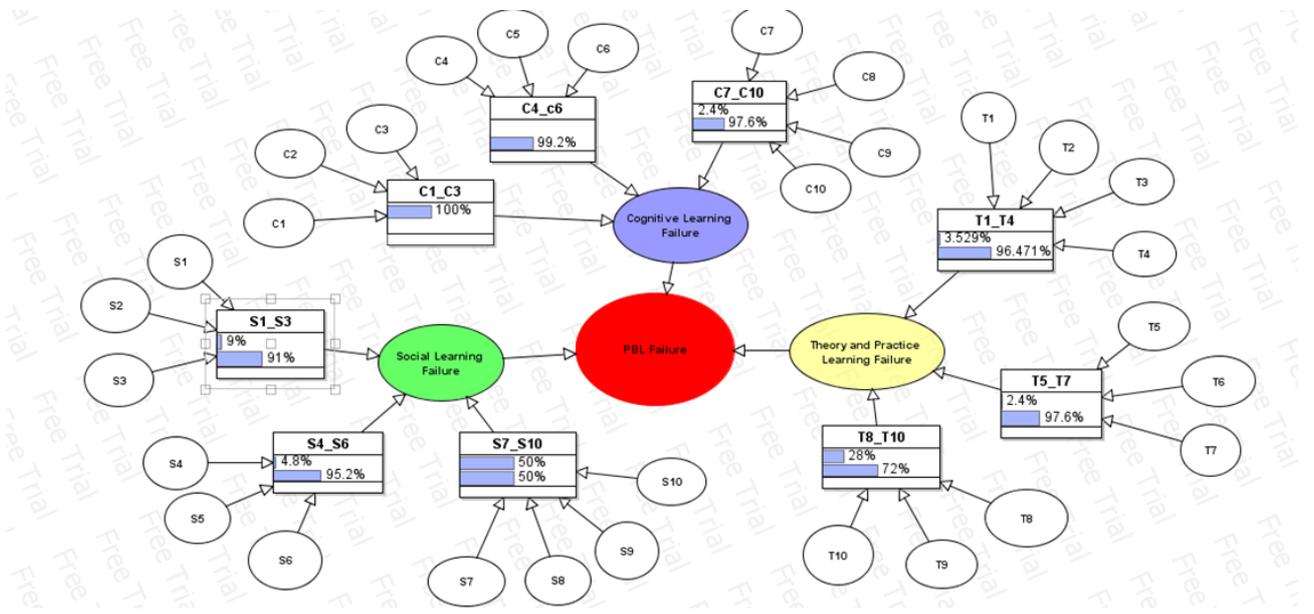


Figure 3. BBN combines all risk factors in the software

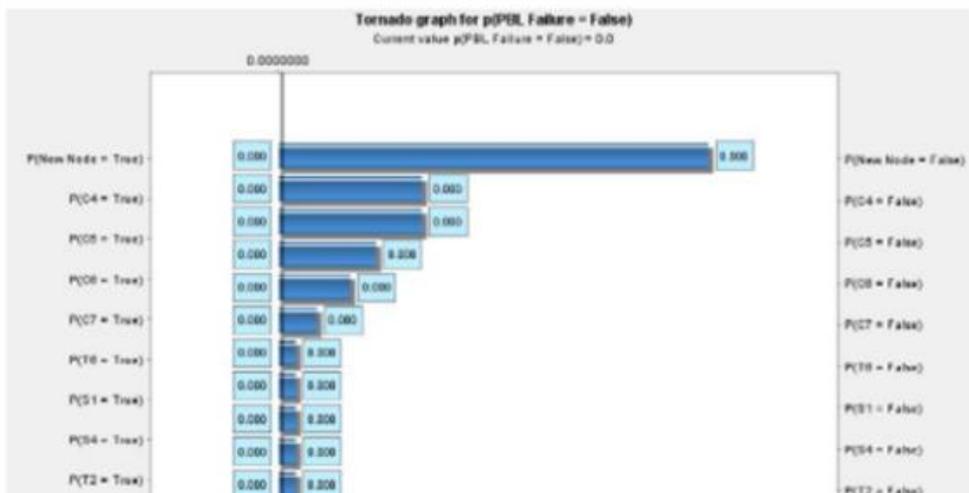


Figure 4. Tornado Chart

The Tornado chart originated from BBN (Figure 4) shows that the risks with the highest probabilities are shows that the highest risk Index is C4 (Poor explanation of expectations to students), C5 (Lack of background definition on principles behind projects), and C6 (No clear definition of requirements). The actions to be taken for risk factor C4 are ensuring the procedure clarifies expectations to the Professor and students. The procedure needs to be detailed enough to ensure repeatability and reproducibility. The action for risk factor C5 is to ensure the procedure also covers the principles behind the projects. The detailed explanation of the objectives and targets of each project is crucial to keep everybody in the same page. The action for risk factor C6 is to ensure the procedure covers the definition of project requirements. If the project requirements are not defined, it is difficult to monitor and control the performance.

5 Discussion of Results and Conclusion

As proposed in the introduction, the study demonstrated that AHP in conjunction with BBN could be used to assess and prioritize the risk factors of PBL failure in future studies. An in-depth analysis of current literature about the subject allowed the identification of risk factors in this process. The preparation of a global risk matrix is proposed since it provides critical information considering identifying and prioritizing the potential risks that could cause PBL failure. It is an effective decision-making process for universities. This study shows evidence that PBL, in general, is subjected to a great variety of risks, some of them capable of compromising the teaching quality in the universities. Probabilistic risk analysis plays a significant role in understanding and implementing risk responses to avoid failure. An in-depth search for previous work dealing with risks in PBL was conducted and is described herein, and a model is proposed for risk assessment. This study is significant because understanding the significant risks in the PBL process can influence the decision of professors and university engineering school coordinators. Applying this innovative risk assessment method in the PBL process fills a gap in the literature since no previous work dealt with this specific 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 proposed, a model for risk assessment of PBL failure is being proposed that allows the combined application of AHP and Bayesian Networks to prioritize risks. The proposed application sought to analyze and define the primary risk factors and critical events that could lead to a failure in PBL.

In response to the first question, "1 - What are the most significant risk factors for using PBL in collaboration with local companies when teaching engineering students?" The most significant risks were identified. The Tornado chart originated from BBN (Figure 4) shows that the risks with the highest risk Index is C4 (Poor explanation of expectations to students), C5 (Lack of background definition on principles behind projects), and C6 (No clear definition of requirements). The result of AHP for the Cognitive Learning principle shows that the most impactful risk factors are C1 (Lack of procedure for the PBL process) and C3 (Lack of standard work for the execution of PBLs). The AHP for the Social Learning principle shows that the most impactful risk factors are S3 (Assign students to teams rather than let them select the team themselves) and S6 (Students not encouraged by professors). The AHP for the Technical Learning principle shows that the most impactful risk factors are T3 (Lack of professor technical content knowledge and experience) and T4 (lack of industrial skills). The AHP for risk factors categories shows that the most impactful risk factors are CA (No Standardization of PBL Procedure) and CB PBL specific requirements not defined accurately).

In response to the second question, " What are the probability and the impact of these risks and the global risk scores? " The probability and impact (global risk scores) for all the risks are provided. The Probability and Impact Score for Cognitive Learning Failure shows that the highest risk Index is C1 (Lack of procedure for PBL process), and C2 Students and professors are not appropriately trained on the PBL procedure). The Probability and Impact Score for the Social Learning Failure shows that the highest risk Index is S3 (Assign students to teams rather than let them select the team themselves), S6 (Students not encouraged by professors), and S9 (Relationship professor and student not good). The Probability and Impact Score Theory and Practice Learning Failure shows that the highest risk Index is T4 (Professor has no industrial skills) and T3 (Lack of professor technical content knowledge and experience).

In response to the third question, "3 What are the responses to high Index risks, and how to combine the risks and conduct a sensitivity analysis with BBN" The responses to high index risks are the following: The actions to be taken for risk factor C1 are the issue of a procedure to document the PBL process. Risk factor C2 is to train professors on the documented procedure. The actions to be taken for risk factor S3 are not assigning the students to the PBL group but letting the student choose the group he wants to work with and the action for the risk factor. S6 trains professors to encourage students to work on the PBL, and S9 provides training on team building to professors and students. The actions to be taken for risk factor T3 are ensuring the Professor assigned to a project has the required technical knowledge and experience. The action to risk factor T4 is to ensure the Professor has practical experience in the industry where the PBL project will be developed. A sensitivity analysis with BBN. The Tornado chart shows that the risks with the highest probabilities are shows that the highest risk Index is C4 (Poor explanation of expectations to students), C5 (Lack of background definition on principles behind projects), and C6 (No clear definition of requirements). The actions to be taken for risk factor C4 are ensuring the procedure clarifies expectations to the Professor and students. The action for risk factor C5 is to ensure the procedure also covers the principles behind the projects. The action for risk factor C6 is to make sure the procedure covers the definition of project requirements.

The target of the study was to identify the critical risk factors that could affect PBL and propose an optimized process that has quality in PBLs. The implications are relevant since changes in the PBL process can improve the result substantially. By following the revised process, PBL failures can be prevented. The proposed Methodology 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. It is believed that the present study will augment the knowledge of professors, engineering students, and engineering school coordinators and help in the application process. As explained in the Introduction Section, several papers have been published addressing PBL use in different domains in the latest years. However, no previous study could be found covering the application of AHP and BBN to identify risks of the application of PBL. It is noteworthy that this paper proposes an optimized approach that could be used in any university or teaching organization.

This proposed process can guide the universities under the traditional teaching process to achieve quality improvement by following the proposed Methodology. That helps to impact results, representing considerable teaching gains significantly. 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 the use of the PBL process to improve the quality and effectiveness of the teaching. Scope for future research: This study opened some new research avenues for the future. Opportunities for other case studies are abundant. They could be related to a broader application of risk analysis of PBL in specific cases, enhancing the current Methodology in use and reducing the risk of failures.

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Engaging with real-world phenomena through Matlab programming projects

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Abstract

This presentation aims to report a pedagogical experience carried out in a course unit of a graduate programme in Computer Engineering at the University of Minho. The course unit, Numerical Methods and NonLinear Optimization (NMNO), integrates the first semester of the third year. The experience took place in 2021-2022 with 146 students, and it was supported by Centre IDEA-UMinho within the project 2Be-Learning. The classes were taught face-to-face (theoretical lectures and lab practice) and several strategies were implemented to support learning: ARS, padlet, videos, storytelling, and projects. Assessment was diversified and distributed over time to foster ongoing study and progress. It included two face-to-face written tests, four online multiple choice mini-tests (one per month, lasting about 10 minutes, based on extensive question banks), and one Matlab project. The focus of the presentation is on the impact of Matlab projects in the learning process. The projects were carried out by teams of 4 students. Each team could choose one of five proposed topics. The main challenge was to search for and select a real-world phenomenon where the chosen topic could be applied and solve a problem that should have an adequate level of complexity. The experience was evaluated on the basis of the quality of projects, students' grades and their perceptions collected in a survey at the end of the course unit. Results show that students developed their creativity through building bridges with other scientific areas and solving problems in innovative ways. Projects promoted their involvement in learning, autonomy, cooperation and the personal construction of knowledge, which are essential competences for lifelong learning. Overall, it can be considered that engaging with real-world phenomena creates conditions for students to connect course-based learning with authentic situations, analyse and solve problems from a multidisciplinary perspective, mediated by digital technologies, and become pro-active learners.

Keywords: real-world phenomena, projects, problem-solving, maths education.

1 Introduction

The Centre IDEA-UMinho (Centre for the Innovation and Development of Teaching and Learning - <https://idea.uminho.pt/pt>) is an academic development centre at the University of Minho that supports the development of innovative pedagogical projects where faculty assume the role of teacher-researchers, exploring and assessing their teaching experiences with a focus on student learning. These projects represent cases of the Scholarship of Teaching and Learning (SoTL), whereby teachers inquire into their practice and make teaching "community property" by sharing and disseminating results so that others can build on their work (Shulman 2004). By inquiring into teaching, teachers become agents of change and reshape their professional identity, which supports the development of culture of innovation that assigns teaching a more visible role in higher education institutions (Vieira, 2014).

The first author started her journey of pedagogical inquiry in 2020-21, during the COVID-19 pandemics, by exploring a b-learning approach in a course unit of a master's programme in Computer Engineering at the University of Minho, Numerical Methods and Nonlinear Optimization, which is placed in the first semester of the third year of the programme (Monteiro et al., 2021). Her project was supported by the Centre and the second and third authors acted as mentors. The goal was to enhance students' motivation, interaction and participation in learning. Along with the exploration of digital resources, assessment became more diversified and distributed over time to foster ongoing study and progress. It included mini-tests and two Matlab projects carried out in teams with the main challenge of finding a real-world phenomenon for the application of a course concept, which implied connecting conceptual learning with reality and creating bridges with other areas of knowledge. The experience was evaluated on the basis of students' assessment results and their

perceptions collected in a survey. The new approach resulted in high levels of student engagement and satisfaction, promoting cooperation and the personal construction of knowledge, which are essential competences for lifelong learning. Nevertheless, it was concluded that the development of Matlab projects required further improvements, not only as regards support to students but also the evaluation of their impact on learning. Therefore, the project was continued in 2021-22 with a new group of students, and the purpose of the present paper is to report the improvements made and the impact of Matlab projects on learning. This project was also supported by the Centre and accompanied by the same colleagues as mentors.

The paper is organized as follows: section 2 describes the context of the teaching experience and the procedures for developing the Matlab projects; section 3 presents information of those projects, students' assessment results and their perceptions regarding project development and some statistical data; section 4 presents conclusions and future directions.

2 The development of Matlab projects

The experience took place with 146 students in the first semester of the academic year 2021-2022. The course unit has 5 ECTS (European Credit Transfer System) with 140 working hours and consists of two modules: Numerical Methods and Nonlinear Optimization. The learning outcomes are the following: applying computer tools to model physical problems; developing and applying numerical skills to analyse systems; comparing different solutions for numerical problems; selecting, using and comparing different optimization algorithms; developing critical evaluation of results; and using computational tools.

The course unit is taught 4 h a week: 2 h of theoretical lessons and 2 h of practical lessons, all face-to-face. Five practical lessons were carried out in computational laboratories with about 30 students per group, involving four teachers. In these classes, the students solve exercises using the calculator and the software Matlab. The Blackboard eLearning platform (Bb) was used to support the learning process.

One of the learning tasks to assess students on the Matlab programming component is a Matlab project. This project entails linking conceptual learning with reality and is aimed at promoting problem-solving abilities, interdisciplinary learning and cooperation, which are important elements of active learning (Graaff & Kolmos, 2003; Prince, 2004). Connecting the curriculum with real world problems enhances authentic learning and deep understanding (McGregor, 2020), and cooperative learning is especially effective in problem-solving tasks that involve dealing with multiple sources of knowledge and require students to negotiate ideas and decisions (Johnson & Johnson 2014).

The projects were carried out outside the classroom in teams of four elements, formed by the students. Five topics were proposed by the teacher and each team should select one according to their preference.

Project development involved several phases, requiring students to negotiate decisions, do research work, solve problems by applying mathematical knowledge creatively, analyse results and report their work:

- Project guidelines placed on the Bb platform
- Topic selection (one of the five indicated by the teacher)
- Searching for a real-world phenomenon, using several sources
- Mathematical modelling (complexity analysis and adequacy)
- Matlab programming using the corresponding routine
- Numerical experiments to obtain results
- Critical analysis of results
- Report writing (three pages)
- Electronic submission with deadline on the Bb platform

The main challenge of the project, which students usually find to be rather difficult, is finding a real-world phenomenon for the application of a course concept. This was observed in the first experience in 2020/21, where students had to develop two projects, which proved to be time-consuming and too demanding for many of them. This time, they only had to do one project, and before they began, the teacher explained the task requirements as usual, but she also showed them examples of well designed projects developed by former

students, increasing student’s awareness regarding the quality criteria their projects were expected to meet, and giving them a more concrete sense of the type of work they were expected to do. During project development, she held regular support sessions as usual, both online and face-to-face, to help students monitor their progress and overcome difficulties. These procedures were useful to develop students’ assessment literacy and self-regulation skills (Evans, 2003; 2021). In the end, each team presented a 3-page report where they synthesized their project.

3 The nature and impact of Matlab projects

A total of 33 project reports were concluded. In this section, we present the topics and the phenomena they explored, as well as assessment results and the students’ perceptions about the competences they developed.

3.1 Topics and real-world phenomena explored

The five topics teams could choose from are presented in Table 1, as well as the corresponding Matlab routines, the week when the topics were proposed, which depended on when they were explored in class, and the number of projects per topic. The first two topics were chosen by a large number of students (79 %). They found them interesting and it was easier to find real-word phenomena related to them; moreover, the fact they were proposed earlier in the semester also gave students more time to explore them. The topic Numerical integration was not chosen, perhaps because it is more difficult to find a real-world phenomenon; also, the fact that it is very easy to use the corresponding MatLab routine makes it more difficult to be creative and obtain a good grade, since creativity is one of the assessment criteria.

Table 1. Topics and Matlab routines

Topic	Matlab routine	Week (1-15)	Projects
Nonlinear equations	fsolve	4	16
Splines	spline	5	10
Numerical integration	trapz, quad	6	0
Least squares approximation	polyfit, lsqcurvefit	7	4
Nonlinear optimization	fminunc, fminsearch	12	3

As pointed out above, the main challenge of the project was to find a suitable real-world phenomenon where the chosen topic could be explored. Despite the strategies used to support the students, this difficulty was mentioned in all the reports and the students complained about it during project development, asking for the teacher’s help. Some ideas were suggested to them by referring to books, articles, magazines, other course units, databases, etc. The identification of a taught concept (topic) in the in the real-world is a mechanism to facilitate conceptual understanding, although it may be quite demanding.

Table 2 shows the variety of real-world phenomena explored for each topic and the scientific areas with which bridges were established. It illustrates the potential value of projects in promoting the connection between theoretical learning and reality, as well cross-disciplinary learning,

Table 2. Real-world phenomena and scientific areas in Matlab projects

Topics	Phenomena	Scientific area
Nonlinear equations	Carbon 14 dating	Chemistry
	Global Positioning System (GPS) using satellites signals (2)	Spatial engineering
	Temperature distribution in a wire	Materials engineering
	Tank sizing	Civil engineering
	American soccer ball throw	Physics

Topics	Phenomena	Scientific area
	Electric circuits (2)	Electrical engineering
	Concentration of a polluting bacteria in a lake	Environment
	Location of a bridge over a river	Civil engineering
	Orbit of celestial bodies	Astronomy
	Electrical power system planning	Electrical engineering
	Efficient square root calculation	Mathematical computational
Splines	Objects design	Computer graphics
	Pathfinding (2)	Video games
	Cryptocurrency price	Economy
	Apparent visual magnitude of a star	Astronomy
	Portuguese students in higher education	Sociology
	Parachuting jump	Physics
	Electrocardiographic heart rate monitoring	Electronics
	Graphic contour of the heart left ventricle	Biomedicine
	Cod fishing in northeast Atlantic ocean (1960-2019)	Business
Least-squares	Average temperature in Lisbon since 1960	Environment
	Portuguese population 1960-2020	Sociology
	Microchip and processor industry (Moore's law)	Electronic engineering
	Soccer players running speed	Sports
Nonlinear optimization	Evaluation of optimization algorithms	Informatics
	Iron barrel sales	Business
	Truck and sedan resale prices	Retail

3.2 Assessment results

In each team, all members had the same mark. This was assumed in the beginning of the semester, but it was also pointed out by a few students as a negative factor in the final assessment, because it did not take account of individual differences among team members regarding their investment and contribution to projects.

The assessment criteria were explained to the students. A scale from 0 to 3 points was used (the course unit has a scale from 0 to 20, the project is worth 15 % of the final grade). The quality of projects was assessed taking into account their originality, complexity, creativity and the computing experiences. Reports were assessed in terms of rigour, ability to synthesize, organization, presentation and the final conclusions. Grading projects is not an easy task and has to be done in comparative terms, i.e., each project is compared with the others, which makes it an iterative, time-consuming process.

The distribution of grades is presented in Figure 1 – 9 teams (27 %) obtained the maximum grade (3). The lower grading in 8 projects (below 1,5) is related to factors such as inappropriateness of the topic to the phenomenon, low complexity, or low commitment to report writing. Overall, students' results were positive and demonstrate that the learning outcomes for this task were globally achieved.

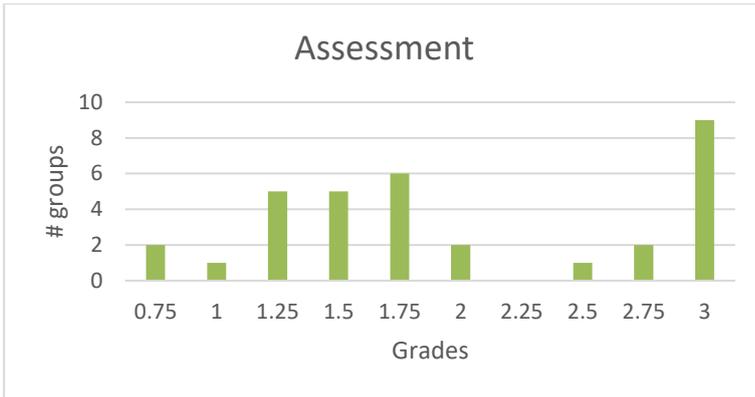


Figure 1. Project grades

The students' final grades showed an approximately normal distribution (Fig. 2), but project grades were not normally distributed (Fig. 3). We used a non-parametric test to look for correlations between the two sets of data. We calculated the Spearman correlation coefficient using ranked project grades and ranked final grades. The result was 0.52. This means that there is a moderate monotonic relationship between project grades and final grades. While both grades tend to go up in relation to one another, this relationship is not very strong because there is a significant number of cases where this is not true.

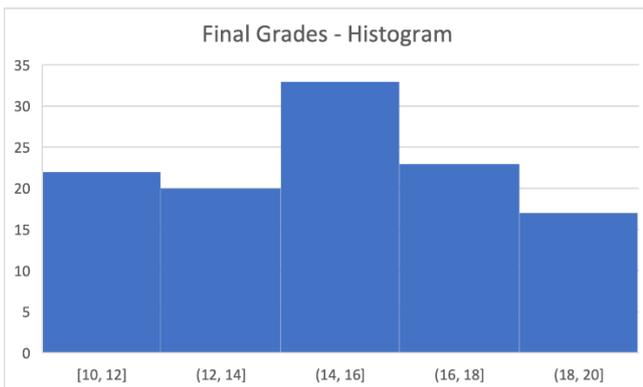


Figure 2. Final grades histogram

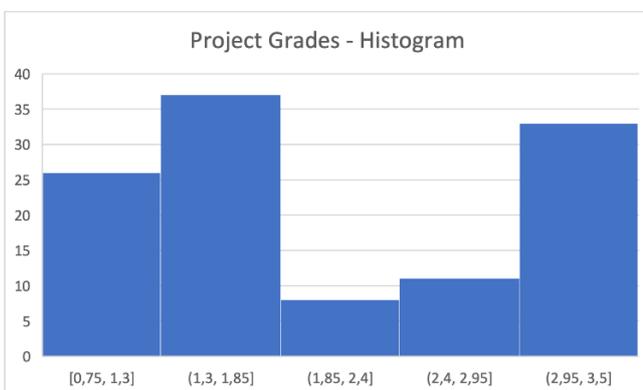


Figure 3. Project grades histogram

However, when we consider the project grades average for each range of final grades: [18,20], [14,17], [10,13], <10, we find out that final grades and project grades are strongly related. An increasing monotonic relationship between the two sets of values is shown in the Table 3. In other words, if a final grade x is higher than a final grade y , then the project grades average A_x corresponding to the range to which x is belongs is never lower than the project grades average A_y corresponding to the range to which y belongs.

Table 3. Project grades average per final grades range

	Project grades average ([0,3]) per final grades range			
Final grades range	[18,20]	[14,17]	[10,13]	<10
Project grades average	2.769	1.877	1.695	1.583

A relationship was found in the results concerning the project topics (cf. Table 1). On average, Splines projects were much better than any other projects. The difference between the average grade for Splines projects, 2.82, and the average grade for Nonlinear optimization projects, 1.75 (the second best group of projects), is approximately 1. On the other hand, the average grade of Nonlinear optimization projects differs only 0.08 and 0.3, respectively, from the average grades of Nonlinear equations projects and Least-squares projects. This may be due to the fact that Splines are important and useful concepts for the Computer Graphics course and their application on various areas is easily understood by students.

Another interesting relationship concerns project grades average for a given topic and final grades average of the students that chose that topic. There is an increasing monotonic relationship between the two sets of values, as shown in Table 4. In other words, if project grades average for topic x is higher than project grades average for a topic y , then - on average - students who chose topic x got higher final grades than students who chose topic y .

Table 4. Grades per topic

Topic	Project Grades Average per topic	Final Grades Average per topic
Nonlinear equations	1.673	13
Splines	2.824	16
Numerical integration	-	-
Least squares approximation	1.45	12
Nonlinear optimization	1.75	14

3.3 Student's perceptions

In the end of the semester, in order to identify the impact of the teaching approach and to collect some information and suggestions for improvement, a short Google forms survey with some questions was implemented. 60 students answered the survey (around 40 %). The survey included two questions on the impact of projects, which were not asked to the students from the previous experience.

One of the questions was related with the usefulness of the project in learning. Students were asked to indicate how useful the project was for their learning in the course unit, using the following scale: 'a lot', 'a little', 'not at all'. 38 % answered 'a lot', 47 % 'a little' and 15 % 'not at all'. These are not very positive findings. However, the findings from another question regarding cross-disciplinary competences developed through projects suggest otherwise. That question presented a set of six competences related to project development and students were asked to indicate whether they developed those competences by doing the project, using the same scale: 'a lot', 'a little', 'not at all'. The results are presented in Table 5.

Table 5. Competences developed through projects: students' perceptions (n=60)

Competences	A lot	A little	Not at all
	%	%	%
Autonomy	51.7	41.7	6.7
Cooperation	55	41.7	3.3
Creativity	63.3	33.3	3.3
Building bridges with other scientific areas	53.3	40	6.7
Personal construction of knowledge	58.3	35	6.7
Solving problems	63.3	33.3	3.3

Around half of the students answered 'a lot' on all competences, and almost all students felt they developed them to a higher or lower degree ('a lot' or 'a little'), which is quite expected given the variability and idiosyncrasy of competence development. The number of students who answered 'not at all' is minimal. These findings appear to suggest that students acknowledged the role of these projects in developing cross-disciplinary competences that are crucial for lifelong learning, namely creativity, personal knowledge construction and problem-solving. A majority of students also considered to have developed autonomy, cooperation and multidisciplinary learning through projects.

It is possible that, in assessing the usefulness of projects for their learning in the course unit, the students were thinking more about disciplinary competences, namely those needed for exams and tests, which may explain the less positive findings on that question. If this is so, then we need to ask whether the students really valued cross-disciplinary competences in their learning, even though they realised to have developed them. Perhaps the fact that these projects were not rated high for their overall grades (3 points in 20) conveyed a conflicting message about their value for learning. These students also took two tests and 4 short multiple choice tests, which accounted for most of their final grade. One needs perhaps to reconsider the relative weights of assessment tasks and whether they are aligned with the value assigned to the various competences those tasks are expected to promote

Let $[0,2]$ be the range of values that represent the degree of students' perceptions of competence development in projects, where 0 stands for "no development", 1 stands for "a little development" and 2 stands for "a lot of development". In this range, a competence is considered relevant if its value is no less than 1.5. Table 6 describes how the students of four different grade ranges ($[18,20]$, $[14,17]$, $[10,13]$, <10) evaluated the development of the several competences through projects.

Table 6. Average development of different competences per final grades range, where development $\in [0,2]$

Competence	Degree of involvement ($[0,2]$) of each competence per final grades range			
	$[18,20]$	$[14,17]$	$[10,13]$	<10
Autonomy	1.563	1.536	1.222	1
Cooperation	1.563	1.607	1.333	1.167
Creativity	1.688	1.714	1.444	1
Building bridges with other scientific areas	1.563	1.464	1.556	1
Personal construction of knowledge	1.75	1.464	1.444	1.167
Solving problems	1.75	1.571	1.667	1.167

For students in the highest range of grades, all competences were solidly developed through projects. Problem-solving and personal knowledge construction scored rather higher than others. For students in the [14,17] range, all competences were developed, with creativity scoring rather higher than others. For students in the lowest range of grades, only two competences were solidly developed: multidisciplinary learning and problem-solving. Creativity and personal knowledge construction were fairly developed, but autonomy and cooperation less so. These findings indicate differentiated perceptions of learning in the three student groups, suggesting that those who had higher grades also perceived a higher degree of competence development through projects

Let students' perceptions of motivation be represented in the scale [0,4], where 0 stands for "not motivated at all", and 4 corresponds to maximum motivation. As it would be expected, perceptions of motivation and final grades are strongly correlated. As motivation increases, final grades increase as well (Table 7).

Table 7. Average motivation per final grades range, where motivation $\in [0,4]$

	Degree of motivation ([0,4]) per final grades range			
Final grades range	[18,20]	[14,17]	[10,13]	<10
Motivation	3.25	2.893	2	1.333

4 Conclusion

The findings showed that project development enacted some of the conditions for creating 'situated learning environments' in higher education as pointed out by Herrington (2006):

- an authentic context that reflects the way knowledge will be used in real life: by identifying real-world phenomena and applying acquired knowledge to solving problems, projects enhanced students' ability to use that knowledge in an authentic context, and also to undertake interdisciplinary learning;
- authentic activities which have real-world relevance, and which present a single complex task to be completed over a sustained period of time: project development integrated a set of tasks that can be transferred to other real-life situations (negotiating decisions, team-building, solving problems, etc.);
- collaborative construction of knowledge, along with coaching and scaffolding by peers and teachers: in developing their projects in teams and with regular teacher support, opportunities for cooperative learning were created, which enhanced students' confidence and motivation;
- authentic assessment by integrating learning and assessment into the same task: projects were learning tasks and also learning products to be assessed, which means that the focus was not only on assessing outcomes but also, and most importantly, on creating conditions for the development of disciplinary and cross-disciplinary competences.

The changes made in students' preparation for projects were useful, yet they still had difficulties in relating course contents with real-life phenomena at the initial state of their projects. Further support might be needed at that stage and during project development, for example through joint seminars on theory-practice integration with realistic examples. Nevertheless, it is also our conviction that students' struggle to make connections between concepts and real life is a necessary part of 'learning beyond the classroom'.

Assessment results and students' perceptions of learning through projects were globally positive. However, more thought is needed on the importance they give to cross-disciplinary competences, and on the role that assessment might play in valuing those competences in grading systems. These concerns may be the starting point for further developments in the teaching approach, which may require the involvement of students in discussing these issues among themselves and with the teacher during the development of projects.

By supporting the development of teaching projects, the Centre IDEA-UMinho enhances collaborative forms of SoTL where mentors act as critical friends. This process creates conditions for the professional development of both the teacher and mentors, who in this case belong to different disciplinary fields. It also favours the enactment of two basic principles of good SoTL practice pointed out by Felten (2013): inquiry focused on

student learning and conducted in partnership with students. The process of sharing experiences and interpretations with others increases our attention to learning and our ability to develop dialogic pedagogies.

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Circular Economy Implemented in a Cosmetic Company: a Case Study

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Abstract

This research was part of a Scientific Initiation Project developed during last year in the Industrial Engineering Program as complement of the undergraduate contents. The purpose of this work was to encourage the adoption of the concept of Circular Economy by the companies regardless of your size in order to reduce environmental impact and help to avoid the malefic effects produced by the tailings discarded by the majority of the companies. This research was based on an extensive literature review and on the formulation of a case study, which was implemented and fully assisted by the Cosmetic Bio Phito Therapeutical Company. Using the assistance offered by the Enterprise Resource Planning tool (ERP), it was possible to infer a mere substrate whose only purpose was to support the raw material that would effectively be used to an applicability that, besides being profitable, brought circularity to the operational flow. The results obtained with the implementation of the Circular Economy brought to the company that was studied the opportunity to avoid inadequate waste management, in addition to a financial savings of around U\$ 2,000 per month due the reduction of expenses with a material that, instead of being improperly discarded, was reprogrammed for practical use, through recycling. The research was developed using the Problem Based Learning (PBL) approach and hands on activities during all the work.

Keywords: Circular Economy; raw material; Enterprise Resource Planning; recycled.

1 Introduction

Since the beginning, more specifically around 10 thousand years ago, the history of mankind was in the Upper Paleolithic period. A milestone in Prehistory in which the Cro-Magnon Man, a primitive population of the species Homo Sapiens, had already developed their first tools, still with limited sophistication, given the incipience and simplicity of the techniques used, defining characteristics of this revolutionary moment in History.

From this point on, great waves were responsible for changing the course of humanity.

From the stone age to the beginning of the First Industrial Revolution. The, until then, hominids left the savannah and began to compose a new class that emerged in History, called artisans, the first industrialists on a modest scale.

Urban landscapes were radically changed, just as they made way for a vertiginous, unplanned urbanization, recurrent throughout Industrialization.

According to Schwab (2018) the Industrial Revolution in the 18th century brought several transformations in the production means and in the European urban scenario. With the industrial rise, handcrafted manufactures and productions were quickly replaced by a scenario of incessant search for technological development, arising from the abundant thirst for productivity.

Baine (2012) said that the Green Engineer must be one of the Engineering careers responsible to save the Earth, creating the infrastructure and means for impoverished countries to have access to clean water, electricity, and internet services to maintain the Sustainability of the planet. The circular economy is a concept of a true sustainable economy that it works without waste, save resources, and works with synergy with the biosphere.

Instead of looking at emissions, subproducts, and damaged or unwanted goods as waste or garbage, these materials in circular economy become raw materials and inputs for a new production cycle.

Throughout the consecutive Industrial Revolutions, certain triumphs became noteworthy, namely: machinery, the progress of means of transportation, the advance of intercontinental communication, the advent of the Internet and new technologies, resulting in the expansion of the, until then restricted, Globalization.

From the mitigation of infant mortality, good quality and life expectancy to the approach of the numerical, Campos et al., (2011), for the levels of education, health, and income, according to the HDI indicator. From high levels of education and literacy to high per capita income. It is palpable that these Revolutions, including the most recent one, the so-called Industry 4.0, have been responsible for significant improvements in the welfare of society, especially in the so-called developed countries. However, their price is being charged.

The human population continues to grow exponentially around the world, with the imminence of reaching a population of about 10 billion people by the year 2050. Therefore, the combination of population growth and social upswing has put increasing pressure on essential natural resources.

With the atmosphere and oceans overburdened with carbon, coupled with uncontrolled burning of fossil fuels, unprecedented climate disruption is manifesting itself. The enormous extraction of resources from nature, with no or minimal replanting policy, leads to the current emergency of the Brazilian flora, defined by the problems of deforestation and wildfires.

The ocean covers about 71 % of the planet Earth, and the waste generated by human activities is totally dispersed in it.

In almost every corner of the ocean, there are already records of the presence of plastic and microplastics. From the above, science shows that more than 80 % of this material is located decanted on the ocean floor and has been degrading successively into smaller and smaller particles.

Today, humanity is at a turning point.

It has become imperative to carry out emergency planning to ensure the subsistence of the next generations.

To this end, it is unthinkable to conjecture an eventual renunciation of everything that humanity has already achieved. Nevertheless, it is feasible to rewrite the formula that will unveil the secret responsible for perpetuating, in a sustainable way, this new Industrial Age.

According to Stahel (2016), [...] "Today's goods become tomorrow's resources at yesterday's price"

2 Scope

The model with which this scientific study was developed, directly implies rigorous exploratory research through literature review. In addition to the meticulous analysis and investigation of previously published theoretical material, field research was also proposed.

According to Powell & Weenk (2003); Kolmos et al. (2009), the Project Based Learning approach (PBL) is a very important method of Engineering Education and put the students in a real contact with the professional environment where the students will be work in the future. To get this knowledge is necessary that the students participate from the start of the project to the final step to learn all the steps and learn to read and implementation of the project.

Campos et al. (2012) show how to create an environment of learning, mainly using, a hands-on activity based on the PBL approach.

Lima et al. (2014) shows as is important the projects developed with the Industry for the development of Professional Competences in Industrial Engineering Education.

Based on these concepts we decided to use PBL approach in this research.

This comprises data collection, which suggests an interpretation of the results obtained.

Conducted right in the original environment where your object of study is located, field research results in accurate, timely, and exceptionally efficient analysis.

In line with both pillars, a Case Study was also introduced. As this is still a little explored theme and little diffused in the market, opportunities for development in techniques and business models that apply Circular Economy in practice, as an inherent part of the production line, can be evidenced.

A Chemical Industry, from the Cosmetology field, was selected for the deepening of this study and the introduction of the concepts of circularity in the daily life of a Small Business Company. Small businesses are made up of micro and small companies and individual micro companies. In Brazil there are on average 6.4 million establishments and, of this total, it is measured that 99% are registered as micro and small company. That said, it is demonstrated as a niche of strong representation in the Brazilian scenario and as an opportune chance to be demonstrated through example, data and proven results, that it is an action whose applicability depends on few resources; low investment cost; and is still able to result in the reduction of materials held in stock, reducing storage costs, increasing the turnover of inputs and the protection of the amount of its working capital. Finally, it ensures a better financial planning of the company and a redistribution of investments. Thus, the focus shifts to improvements in the production belt and, in a possible automation, in the means of production.

This proves, therefore, the endless returns that are generated for society, in terms of sustainability and environmental preservation, as well as the positive cycle that is incited.

According to what was said above, this study aims to demonstrate that the practice of Circular Economy should not be restricted to large industries, nor does it require the export of technologies to be feasible, on the contrary, implementing a system that brings circularity to the process allows all companies to have an experience of intelligent manufacturing, in which natural resources are saved, the destination of cash flow is reconfigured, and therefore new technologies arising from Industry 4.0 can be implemented, democratizing competitiveness within the national market itself.

3 Applying Research in Engineering Education

When focused on the educational context, this study addresses efforts to improve logical investigation skills and to improve the search for solutions to overcome the obstacles presented, which are intrinsic characteristics of an engineering education.

Aiming to acquire this knowledge to conduct efficient research, with results that are tangible to reality, notes were taken on articles presented at the UNESP Symposium of Industrial Engineering (SIMPEP), in 2020, through which it was possible to understand more clearly the characteristics that differentiate Circular Economy from a Recycling Process, for example, among other details that highlight the importance of this concept today.

It's important to highlight some academic-scientific-cultural activities promoted by the Pontifical Catholic University of São Paulo, which were of immeasurable contribution to the formulation of this research. These activities consisted, mainly, of lectures and seminars that dealt with subjects of fundamental importance to the development and conclusion of the chosen thesis. Some of the subjects approached were The Future of Industry; Prototyping Technology Applied to Factory 4.0; Use of Technology in Small Business and Opportunities of Waste Management.

Finally, the experience obtained by following the daily routine of the factory floor, in the industry selected for the application of the Case Study, was extremely enriching at the juncture of studies, aiming at a future training in the Engineering career. There, it was possible to learn about the manufacturing processes, how the organizational structure of a company works, the obstacles faced during production management, planning strategies and risk analysis, financial control, and, focusing on the theme of this project, the most appropriate methods of waste disposal and management. The purpose of the study was to reduce the generation of production waste to as close to zero as possible. This opportunity of proximity with the cosmetics industry Bio Genetyc, also allowed to acquire the knowledge of using the Corporate Software ERP (Enterprise Resource Planning). This technology is becoming more and more usual in Engineering and, frequently, required in the management areas because it makes possible to analyse and follow up each step of a production process,

besides allowing a rigid stock control. The ERP tool helped, rigorously, in the monitoring of each result obtained.

4 The Circular Economy

Due to the usual logic of extraction, production, consumption, and disposal, humanity has submitted itself to a Status Quo limit situation. The, until then, trivial model of traditional and linear economy has suffocated natural resources and expressively mitigated the quality of life of the inhabited environment. Emerging as an alternative to contain the consequences that this and the next generations will be subject to face, a definition emerges in defence of the operating modes that surround the sustainable model.

In 1989, what is today an integral part of the lexicon of the economy, namely known as Circular Economy, was born.

Elaborated in an autonomous article by British economists and environmentalists David W. Pearce and R. Kerry Turner, it was demonstrated, through analysis, that the environment was totally disregarded in the unbridled search for the consumer market and the desire to gain a position of influence among the capitalist nations, an episode reinforced and contextualized in the midst of the Fall of the Berlin Wall (1989), which culminated in the end of the Cold War and caused, subsequently, the dissolution of the Soviet Union.

At the time, the environment was bequeathed a secondary role, as a simple waste reservoir. Also known as "cradle to cradle", Circular Economy does not work with the idea of waste, after all, everything can be progressively reused in a new cycle. In other words, by designing the product design in its entirety before manufacturing it, it was possible to avoid the use of materials that cannot be reused, so that all creation returns to the production cycle, drastically limiting waste generation.

According to the United Nations (**UN**) and the Circle Economy report, only 9 % of the global economy is circular, which in practice confirms that of the 92.8 billion tons of waste generated by industrial and residential means, less than 10 % returns to the production chain, that is, more than 80 billion tons of plastics, fossil fuels and biomass are inadequately disposed of to the environment.

Essentially, Circular Economy is based on value creation through a "closed loop", in which industrial and social evolutionary concepts aim to achieve integral sustainability objectives in relation to a no-waste philosophy, starting from a regenerative system.

4.1 The Waste Management Issue

Waste, on the other hand, pragmatically suggests an extra cost within a corporation and, accordingly, has a negative impact on its reputation, depending on the type of disposal that is routinely performed. To this end, the Federal Accounting Council (**CFC**) has been orienting accountants to bring these environmental points to the balance sheet of their partner companies, aiming at the lowest wear and tear not only to the already scarce natural resources, but also to the very image of the corporation in question and, consequently, aspire to the protection of the balance sheet in view of inspection agencies, such as: the Civil Police, CETESB, and the Sanitary Surveillance.

Currently, inadequate areas of final disposal, such as dumps, and controlled landfills receive an average of 80 thousand tons of waste per day. These are 80 thousand tons that could be redirected and better used, by transforming them into by-products. However, the consequences for this phenomenon called, Inadequate Waste Management, are impacted soil; impacted groundwater; impacted rivers and lakes; spreading vectors and, because of these calamities, human beings are fervently impacted.

Between the years 2017 and 2018, the generation of MSW (Urban Solid Waste) in Brazil increased by almost 1%, reaching the mark of 216,629 tons per day. As the population also grew in the period (0.40 %), the per capita generation obtained a minimally reduced elevation (0.39 %). This means that, on average, each Brazilian generated a little more than 1 kilo of waste per day.

However, taking into account the contemporary atypical situation in which society has been subjected, it is important to take into account the change in this statistic, given that in 2020 and 2021 the number of food orders via apps will expand exponentially, causing a predicted increase in the number of disposable packages that lead to an extreme increase in waste originating in homes and likewise, as a reflection of the pandemic, a radical demand for hospital supplies.

On August 2, 2010, Law No. 12.305/10, better known as the National Solid Waste Policy, was enacted and is fully responsible for organizing the way in which the country manages its waste, requiring from the public and private sectors transparency in the destination and treatment of its waste. This law establishes the principle that everyone, from the person in charge of receiving the raw material to the dispatch supervisor, is fully responsible for the management of these remaining materials.

A viable solution to be undertaken and, increasingly, instituted in reference corporations in the market to encourage their competitors in the industry to apply the same strategy, is the so-called Reverse Logistics.

This instrument consists in the economic and social development, characterized by a set of actions, procedures and means that enable the collection and return of solid waste to the business sector, for reuse in its production cycle or even proposing the realization of a new final route, this time, environmentally appropriate.

These procedures consist, respectively, in reusing or reprocessing the raw material for the production chain; waste generation by the manufacturer (during manufacture); waste generation by the merchant (during commerce); waste generation by the consumer (after use); disposal; voluntary delivery point; collection and recycling; reusing or reprocessing the raw material for the production chain.

All phases, whether of manufacture, marketing, or use, can be returned and reprocessed for the creation of a new raw material, without necessarily having to extract new resources from nature and much less discard the old ones.

The state of São Paulo has been one of the forerunners of the implementation and obligation of Reverse Logistics in more and more products with flammability risk or that, today, have an inadequate disposal.

4.2 The Microplastics Issue

Considered one of the most problematic, dangerous, and difficult to solve issues on this subject, special attention should be paid to the topic of microplastics.

The difficulty of the subject matter becomes clear when, upon reflection, it becomes possible to conclude that every little piece of plastic that has been created to date still exists. Even after reaching its degradation limit year, plastic will never completely disappear, it will only decrease in size. The problem lies in the fact that the smaller the material gets, the easier it is for an organism to ingest it without realizing it, and this can lead to an interaction with different chemical components as soon as it fragments.

Microplastics, when dispersed in the ocean, are often found in plankton, which provide about 60 % of the oxygen found in the atmosphere by carrying out photosynthesis. However, since plankton in the pre-existing food chain relationship also serves as a subsistence for some species of fish, the fish ingest the plastic, and the plastic is automatically incorporated into man's food chain when he feeds on it.

Recent research conducted by European scientists from the Medical University of Vienna has shown, by collecting human excrements from different countries, that all the excrements studied contained more than 50,000 microparticles of plastic each.

Demonstrating at last that the contamination of the garbage has reached our intestines.

Actions admittedly capable of mitigating the existence of plastic in the seas consist of investments to enable the use, productively, of the new bacterium identified in 2016, which is called *Ideonella sakaiensis* 201-F6 and has the capacity to degrade PET, using it as its main source of carbon and energy.

According to Bornscheuer (2016), if terephthalic acid can be isolated and reused, it could generate huge savings in producing new polymers, without the need for petroleum-based feedstocks.

Aggravating factors related to socioeconomic and occupational problems should also be assumed, since in Brazil, the great source of waste that reaches the sea through the watersheds, about 80 %, is located on land roads, mostly from irregularly occupied areas, because there is no collection service and proper disposal of solid waste in these regions.

After all, similarly, considered as a viable option for the resolution of the adversities caused by improper residual disposal, the concept of Industrial Symbiosis is presented. This can be defined as a long-term association between two organisms of different species, i.e., submerging the concept to the corporate environment, it is assumed that the waste generated in one company can be used by another, following the minimization or total elimination of waste.

4.3 Successful Cases

In the domestic sphere, the number of consumers who demand differentiated attitudes is growing, and above all, from the circular economy perspective, they opt for sustainable products and services, in which the responsibility for waste management is planned from manufacturing to the final disposal of packaging after consumption.

Within the cosmetics industry, two companies stand out for their socio-environmental concern: Natura, responsible for launching a challenge to itself which consists in the search for innovative solutions, such as zeroing the brand's packaging waste, has already started to demonstrate positive results for the theme, by declaring that the "**Kaiak Oceano**" perfume packaging is produced with plastic residue of which, at least 50 % of the total of this material that is used in the confection of each packaging, is taken from the ocean and collected on the beaches of the Brazilian coast.

Another even more recent measure taken by the **Natura & Co** group is the launching of its packaging recovery program at its branches located in Mexico. Aiming to be able to contribute even more effectively to reducing the environmental impact generated by improper handling of waste, the Brazilian company has promoted the action "Reverse logistics of post-consumer packaging", with which it invites consumers and its entire network of consultants to join the Circular Economy by taking empty, clean, and dry Natura packaging to any of its physical stores. By participating in the initiative, the contributor will receive 25 % discount on refills for each 5 packages delivered.

"With this proposal we want to invite people to be part of the movement, promoting the circularity of post-consumption packaging, in line with our commitment to be an agent of change that adds value to society and generates positive impacts, achieving a world with more beauty and less waste," said Griscelda Ramos, Director of Sustainability at Natura Mexico.

In June 2020, the 4th largest holding company in the beauty business in the world, which gathers Natura, Avon, The Body Shop and Aesop, presented its plan "*Commitment to Life*", to face the most urgent global problems. Among the commitments highlighted in the document is that of "embracing circular economy and regeneration", to achieve greater circularity in packaging. A clear example of this is in the constitution of the container used for the Natura Ekos and Tododia lines, according to Alves (2017) and the Brazilian company itself, PET plastics from the recovery of bottles that feature this material are used, extending in such a way the useful life, and contributing to its maintenance within a productive cycle.

By implementing these good practices, packaging material is reduced by up to 80%, avoiding more than 3,000 tons of waste annually, as well as the emission of 8,000 tons of greenhouse gases, according to company data. In 2020 alone, Natura managed to recover 667 tons of waste.

Another reference brand in the search for sustainable solutions associated with its products is B.O.B., responsible for offering a bar alternative, aiming at gradually replacing the plastic packaging of shampoos and conditioners.

The digital transformation, although it may seem "cleaner" than its predecessor technologies, will generate a legacy that is even more harmful and difficult to control if not wisely handled. Thus, the Circular Economy coupled with Industry 4.0 arises, intending a sustainable management of the supply chain, through the Internet

of Things, which connects stakeholders to efficient flows of materials and information. Thus, by linking ideas, people and places, the generation of good opportunities is potentialized as a result.

5 The Case Study

After searching for a practical means and a feasible experience for the application of the concept of Circular Economy in an Industry, whose manager is configured in the same classification of Micro and Small entrepreneur, as well as the 99 % of entrepreneurs located in the national territory who, despite all the fiscal disincentive and the lack of credit stimulus with which they are afflicted, it is important to emphasize that they continue to leverage the country's economy by sustaining about 27% of the Gross Domestic Product (GDP) and ensure 54 % of formal employment in Brazil, according to data from **"Brazilian Service Support to Micro and Short Companies" (SEBRAE)**. The idealization of taking advantage of the representativeness that the sector enjoys in the private sector sowing sustainable practices that, in parallel, also play a financially attractive role to the company, was conceived. In response to the above, the structuring of a case study was outlined that, after all the work of elucidating, theorizing, defining which strategies are more palpable and experimenting with possibilities, it was possible to attest to the simplicity with which Circular Economy not only can, but should be present in each stage studied during the formulation of a product and/or in the operational planning that surrounds a production.

The target company of this study was Cosméticos Bio Phito Terápicos Ltda.

Founded in 1984 in the city of São Paulo, Bio Genetyc, the brand for which it is recognized in the market, started its activities manufacturing cosmetics for third parties and for the retail market. Today, with over 30 years of continuous experience acquired, its main focus is to offer products geared to the needs of distributors and clients from the international market, clients who aim to work alongside a company constantly concerned with the quality, sustainability and technological innovation promoted in its merchandise, whose origin is entirely from the domestic industry and each production process, from the development of products to the act of packaging them are thought out and closely monitored by its manager.

With the help of the Enterprise Resource Planning (ERP) tool, it was possible to observe in detail all the production chain related to the industry in question, in order to establish the procedures that, when optimized or possibly replaced by more viable techniques, would achieve tangible results for the corporation, serving as an example for commercial partners and even competitors, whether in the same sector or not, to contemplate the unmeasured benefits that were added after the experimentation of this pilot, encouraging them in such a way, to apply similar methods in their production cycles, expanding the benefits gained in an unprecedented quantitative scale.

For this study, it was selected within the context of raw materials, the roll of labels, thus being elected as the target object, where the understanding regarding the applicability of Circular Economy would be properly tested.

Once the first phase of decision making about the most suitable raw material to undergo the readjustment process was concluded, the possible strategies to implement the concept were defined.

Initially, it was conjectured the use of the smooth roll, making use only of its substrate, without the conjunction of labels on the surface so that it could be reused to wrap the products already boxed, about to be shipped to the carrier.

However, it was noticed the low efficiency in what concerns the protection of the products contained in the box; in the little aesthetic attractiveness given and in the little performance promoted to the material, as much as it was expected when readjusting the utility of its function.

Thus, the idea of using a paper shredder emerged, one of those easily found in offices and accessible in the main stationery stores. The objective is to take advantage of the physical concept that comprises, for example, the springs. By going through the fragmentation process, the paper acquires the property of flexibility, which

enables it to store mechanical energy, making it, therefore, a pseudo-spring able to dampen the movement of objects inside the box during transportation, ultimately avoiding damage to them.

Despite the addition of an extra procedure in the production chain, with the insertion of the fragmentation action, it was possible to verify a significant improvement and a true optimization regarding the amount of material spent, given the increase in volume caused, as well as in the improvement of aesthetics and the benefit of its new assignment.

In short, an investigative process can be evidenced in practice, with a simple, effective, and easily absorbable solution in the day by day of an organization, in which by recovering all its production, a work of identification is carried out on which inputs, products, and methodologies are likely to be incorporated into the closed production cycle.

When one acquires the ability, by observing the whole, to promptly search for the opportunities contained, a ridiculous raw material, in the eyes of the layman, is equivalent to the master key capable of solving an important humanitarian setback, in the eyes of the visionary.

Thus, a mere support for the labels is transformed into a resource of unavoidable usefulness, which is interesting to highlight the fact that it is manufactured with waxed paper or impregnated with impermeable substances, configuring a non-recyclable waste and difficult to compost.

In other words, the technique of certifying the safety provided in the transportation of goods was improved and new costs were avoided with the purchase of materials such as bubble wrap, whose average price to cover a small box is evaluated at US\$ 0.04. When considering a production of 50 thousand boxes per month, it is palpable as a result the conception that just with the implementation of this simple addition of function to a material that would be discarded in the production cycle, besides avoiding an inadequate waste management and an accumulation of materials improperly discarded in landfills, it also brings a saving of about US\$ 24,000.00 for the company per year.

Therefore, the maxim that "waste is nothing more than raw material out of place" is proven.

During the process I was present from the start of the Project till its final, working in all steps in activities hands on.

6 Conclusion

This work brings to me the opportunity to apply several concepts learned in classes and develop in floor of company, competences and skills of engineering professional, based on the confluence generated by the bibliographical review, the field research promoted by the collection of data and experiences of partner companies in the segment, as well as on the empirical investigation on the others authors of this essay, demonstrated as a result the initiation of a transformation in the population's view of the Circular Economy theme, ranging from the micro company to the most knowledgeable CEO in the market.

The consumer market is progressively more demanding in selecting which company value their investment and help to maintain the sustainability of the planet, preserving the natural resources in the production cycle, minimizing the impact generated by the discarding and mitigation of the need for extraction of new inputs taken from the environment. In addition to the sustainable benefit granted to the planet, which will reflect significantly on society, the implementation and insertion of Circular Economy instinctively to the internal flows, is also able to promote a boost in its invoicing, from the economy provided in line with the profitability achieved due to the positive movement that had been promoted, and may even gain important highlights of real relevance to the agenda, raising and consolidating such a way, a consumer market even more reliable.

Finally, this case study presented its role in offering the necessary subsidies for companies inclined to adopt such practices, and can be applied due its simplicity and, synchronically, with the endless constructive return that can be achieved, as evidenced in the calculations and analyses based on the data offered.

Besides that, the implementation of this approach brings financial saves to the companies.

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A strategy to support Engineering Education teaching staff monitoring students' learning process: Metacognitive Challenges

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Abstract

It is increasingly required that Engineering Education courses include activities that promote the development of cognitive skills, such as metacognition. However, including such activities is challenging for lecturers, particularly in Distance Learning contexts. It is also complex, when working online, for teaching staff to carry out monitoring of the metacognitive learning processes of students, understand their difficulties, and provide formative feedback.

In this work, we present the design and discussion of a pedagogical strategy: Metacognitive Challenges (MC), which allows lecturers to monitor the evolution of students' perceptions regarding their learning process. We discuss how lecturers can use MCs for formative assessment and how to weave this intervention with individual students or groups. The Design Science Research methodology was adopted for the design, implementation, and demonstration of MCs, applied in a Software Engineering course within a distance learning Informatics Engineering undergraduate programme. We exemplify how MCs have the potential to support monitoring of students' cognitive and metacognitive processes and offer a set of guidelines on how the teaching staff can use them.

In future work, we intend to evaluate the effectiveness of MCs in different teaching contexts, and develop technological solutions that facilitate the monitoring process (reduce the time and effort required for analysis of MC content).

Keywords: Metacognition; Cognitive process monitoring; Software Engineering Education; Self-regulation and Co-regulation of Learning.

1 Introduction

Increasingly, Engineering Education is committed to active and situated learning, putting students in contact with real engineering experiences (Wengrowicz, Dori & Dori, 2018). In software engineering, the novice-to-expert transition requires students to develop advanced technical skills, namely: large-scale programming and software development processes (ACM & IEEE, 2016), the ability to think abstractly, and the adoption of cognitive and metacognitive strategies (Garcia, Falkner & Vivian, 2018). Major professional organizations in the field (ACM & IEEE, 2016) recommend connecting practical aspects of real practice with educational plans.

Distance learning in universities has expanded. However, this brings novel challenges and dropout is usually higher (Broadbent, 2017; Pedrosa et al., 2021). Students experience difficulties planning, developing, and using self and co-regulation learning (SCRL) skills properly (ibid.), which adds new challenges to online teaching, both regarding course structure and the practice of e-pedagogy (Kara et al., 2019). Strategies that allow lecturers to overcome such challenges include: 1) provide formative assessment; 2) provide timely, continuous, and constructive feedback that facilitates the process of planning, managing learning and problem-solving skills; 3) adoption of appropriate assessment tools contributing to a better optimization of learning; and 4) reflect upon and adjust their pedagogical practices towards enriching students' learning (Kebritchi, Lipschuetz & Santiago, 2017; Kara et al., 2019).

In Engineering Education, the incorporation of metacognition in curriculum plans is advantageous as it helps students improve essential skills and their ability to engage in SCRL (Wengrowicz, Dori, & Dori, 2018; Wallin & Adawi, 2018). Also, metacognitive regulation is a characteristic that distinguishes experts from novices (Kim & Lim, 2019), hence developed in the novice-to-expert transition.

Metacognition is "*thinking about thinking*" (Flavell, 1979) and is understood as knowledge and capacity for self-judgment about one's own cognitive processes and control, that allows identifying successful strategies (e.g., planning, analysis, management), emotional self-efficacy monitoring, and evaluating metacognitive knowledge according to feedback (Wengrowicz, Dori, & Dori, 2018; Prather et al., 2020; Dindar, Jarvela & Jarvenoja, 2020; Schuster et al., 2020). When the student has metacognitive awareness about these strategies, performance improves and success in higher (Davis & Hadwin, 2021; Frasier, 2021).

Metacognition can be understood in two dimensions (Wengrowicz, Dori, & Dori, 2018): 1) The regulation of cognition - which allows students to develop skills, such as: planning, monitoring and evaluation of their tasks, which allow them to take control of their learning; and 2) Knowledge of cognition – which helps students improve the way they learn and solve problems, in conjunction with the regulation of cognition that allows students to acquire key skills in engineering.

Software Engineering requires problem-solving processes; but it is difficult to study cognitive control (Prather et al., 2020). The use of pedagogical strategies that promote the acquisition and use of metacognitive skills by students is crucial to support teaching feedback processes that encourage self-analysis of errors and positive correction (Sáiz-Manzanares & Montero-García, 2015). However, there are few instructional programs that explicitly focus on teaching control and monitoring skills (Schraw & Gutierrez, 2015) and few studies explore the use of strategies that facilitate formative assessment processes by teaching staff (Wallin & Adawi, 2018).

In this work, we present the design of a strategy that we developed, the Metacognitive Challenges – MC (Pedrosa et al., 2021). We discuss how MC can be used by teaching staff to monitor the cognitive and metacognitive processes of students and to provide formative feedback.

2 Teaching context

In previous work, we explained that the concept the Metacognitive Challenges (MC) results from the articulation of the different dimensions that involve a reflexive metacognition process with the concept of challenges (Pedrosa et al., 2021) and reported on the positive perceptions of students about MC: they are perceived as being innovative, motivational, and useful to develop self-regulating learning strategies and greater self-awareness about one's own skills.

The MC were designed within scope of the e-SimProgramming didactic approach (Pedrosa, 2021). This approach was implemented in an online asynchronous course ("Software Development Laboratory", LDS in the Portuguese-language acronym), part of the 2nd semester of the 2nd year of the Informatics Engineering undergraduate programme at Universidade Aberta (UAb), using the Moodle platform. It is organized along a six-topic syllabus with the goal of scaffolding undergraduates transitioning from novice programmers into proficient programmers that acknowledge the relevance of employing engineering structural qualities in the development of their software programs. The students are typically working students, aged 24-60 years old, residing in various regions of Portugal and abroad, with different academic backgrounds. The teaching and learning methodology employ Project-Based Learning, through the development of software projects by students or teams, integrating concepts sequentially throughout the semester (Pedrosa et al., 2020, 2021).

3 Methodology

This work focuses on the problem that the teaching staff faces when monitoring the evolution of cognitive and metacognitive processes of engineering students, which are essential for successful learning, particularly in Distance Learning. We adopted Design Science Research (Hevner & Chatterjee, 2010), which develops knowledge by embodying it in the design, implementation, and evaluation of an artefact. In this study, we

present and demonstrate through examples how Metacognitive Challenges (artefact) can be a strategy that helps teaching staff monitor students' metacognitive processes. We evaluated the examples by collecting data on their use with 32 students (out of 50 enrolled in the LDS) who agreed to participate in this research during the academic year 2019/2020. All students granted their authorization through an informed consent statement.

4 Pedagogical design of Metacognitive Challenges

4.1 Design and implementation:

Two types of Metacognitive Challenges (MC) were designed and implemented (Pedrosa et al., 2021) with different pedagogical goals, timing, and characteristics (see table 1), allowing both students and lecturer to monitor the cognitive and metacognitive learning process of students.

Table 1: Differences between the two types of Metacognitive Challenges (MC)

Dimensions	MC Type 1 Metacognitive challenges as fortnightly reflections about the learning progress	MC Type 2 Metacognitive challenges to promote self-reflection about programming concepts
Pedagogical Goals	Stimulate self-reflection and self-assessment of students about: a) the learning progress. b) the development of the project. c) self-confidence about their work.	Promote students' self-reflection on their ability to apply the knowledge they have acquired throughout the course, regarding the technical aspects of software development processes. Note: For the construction of these MC, in each topic, Bloom's taxonomy was used.
Components of the metacognitive domain	Regulation of cognition: Planning, monitoring (self-awareness), and evaluation (self-assessment).	Knowledge of cognition: Declarative knowledge, Procedural knowledge, and Conditional knowledge. Metacognitive experiences: Feelings and judgments.
When it appears in the course	At the end of each syllabus topic.	At key moments in each syllabus topic (beginning, middle, or near the end).
Number of MC	6	12
Format	Both types of MC have been implemented in Moodle, using the Quiz feature. In the introductory part, a narrative by the fictional Catmming character is used (Pedrosa et al., 2021) that triggers the student's reflection to respond and reflect through prompts (questions in the quiz). The quiz includes Likert-scale closed questions (Very Low; Low; Regular; High; Very High), and open-ended questions where students justify their choice or explain in detail the answer given in the closed question.	
Questions	Standard questions that are adjusted by syllabus topic and the expected development status of the software project.	There are no standard questions. The questions vary according to the metacognitive goals defined for each syllabus topic.
Usefulness for the lecturer	It provides awareness of the student's perception of the learning regulation processes adopted throughout each topic. Identify the type of difficulties; Provide SRL strategies for the student (e.g., planning, time management, seeking help); Checking discrepancies regarding the level of confidence and self-assessment with their appreciation of the work.	It allows the lecturer to infer and formulate formative hypotheses regarding expected skills: whether they were developed, if knowledge was applied correctly, and understand students' feelings and judgments about their technical and knowledge skills.

4.2 Demonstration/Evaluation: How metacognitive challenges help lecturers monitor and be aware of students' metacognitive learning processes?

The Metacognitive Challenges (MC) provide awareness information to the lecturer about the cognitive and metacognitive processes of the students regarding their own learning. With this information the lecturer can define ways of acting/intervene to provide formative feedback for the different situations that occur, in a personalized way (individually) or at the group (class) level.

Ideally, the lecturer should analyse all answers of all students. However, analysing MC is a time-consuming activity. Thus, it is suggested that the lecturer, to gain some awareness about the general panorama of the class, generates response graphs that allow understanding the critical aspects to be solved and define a timeline. We demonstrate and discuss, in the following examples, how to use information from MC to monitor and intervene with feedback.

Example 1 – Motivational intervention

In the question (MC type 1) *“At what level of learning progress do I consider my evolution to be?”*, one can see where most students’ answers are. In the following example (figure 1), most students consider that they are at a *“Regular”* level (satisfactory learning progress).

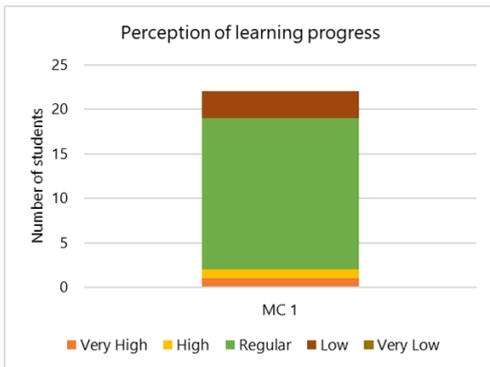


Figure 1: Responses of LDS students for the 2019/2020 academic year to the question *“At what level of learning progress do I consider my evolution to be?”*.

In this situation, the lecturer can decide to focus on students who expressed a *“Low”* level and understand through their answers to the question *“Why?”* the reasons that the students provided. Some examples: *“I started with few bases (...)”*. S21, March 25, 2021. *“I think I still have a long way to go.”* S57, March 21, 2021.

Analysing these responses points towards motivational factors and lack of confidence (or modesty). This may inform enable a teaching decision to provide feedback to the whole class of a motivational nature, weaving a set of suggestions for self and co-regulation of learning strategies (such as suggesting that students seek help from the teacher and colleagues). Or instead provide individualized feedback, or yet another approach. The rationale is that the MC provide a structure for teaching decision-making: identifying focus aspects from the Likert-scale responses and then analysing concrete responses within those focus aspects.

Example 2 - Awareness of difficulties and help students overcome them

The lecturer can identify difficulties reported by students and try to understand them. By analysing the answers to the question: *“Did I experience difficulties in this initial phase of software development?”*, the lecturer may realize, as in our test case, that most students expressed that they felt difficulties (Figure 2).

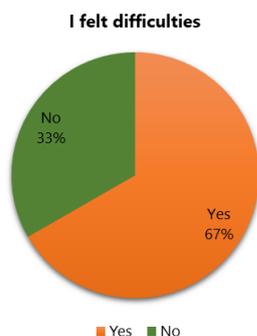


Figure 2: Response of LDS students for the 2019/2020 academic year to the question *“Did I experience difficulties in this initial phase of software development?”* of MC type 1.

The lecturer can try to understand the type of difficulties from the responses to the follow-up question "Why?". In our test case, students reported difficulties of various types, e.g.: *"I had a hard time understanding how to use MVC with the Selenium API (...). (...) the interpretation of the texts, the fact that the links to documents were not highlighted, made me start developing the demonstration application when that was not the goal"*. S56, April 5, 2020.

In this example, one can identify two types of difficulties:

- The student's understanding of the practical application of course material (MVC software architecture) with an API (software development tool). The instructional intervention may be to promote class sharing of specific difficulties or offering individualized help, towards better clarification of these concepts to the student or to the class (knowledge of cognition).
- Understanding specifically which task to perform, from the material provided. In this situation, the lecturer may elect to improve the pedagogical resources for by correcting the next tasks through the placement of visual elements (highlights) and a final task list to help students; or to alert the students in general to check if such misunderstanding occurred to others, etc.

Other responses have shown us that these MC may also expose difficulties not related to the course itself but related to personal lives / professional factors of the students, that affect their self-regulation learning strategies: *"Mainly, personal difficulties led me to compromise time management."* S36, April 13, 2020. This awareness may enable the teacher to recommend activity prioritization for students, plan recovery plans, or other approaches.

Example 3 - Clarification of aspects related to the syllabus and concepts that may be misunderstood

The question *"Were you able to perform all the requested tasks?"*, enables understanding the students' perception of overall task completion. The lecturer can check whether that perception is correct or not. That is, a student can believe that he/she has completed all tasks, but in reality some task may be missing. This awareness may recommend alerting the student or the class, in realization that uncompleted tasks are not simply delayed, but rather disregarded.

Another approach is this case (figure 3), where most students affirmed that they were able to complete all tasks. If this matches the perception of the lecturer, the focus can shift towards the students who indicated "No", to analyse the reasons.

Again, the "Why" questions will be the source of that analysis. Different types of situations can be encountered requiring interventions, e.g.: *"I await feedback (...) to finish this sprint"* S8, April 20, 2020. In this circumstance, there was an expectation of feedback to advance, of which the lecturer might be unaware.



Figure 3: Response of LDS students for the 2019/2020 academic year to the question *"Were you able to perform all the requested tasks?"* of the MC type 1.

Another situation found in this process was related to the student's own technical ability to apply course knowledge in practice: *"I am not able to make user interaction and choice with the API, I changed the model, but it is not easy to be able to make the application according to that design."* S56, May 9, 2020. In this situation, a technical difficulty was exposed (which may even be impacting other students in the class) and provide the

lecturer with an opportunity for general feedback or try to support the student on that specific technical issue (Knowledge of cognition).

Example 4 - Recommendations for adopting learning SCRL strategies

Another MC type 1 question was: *“What are the steps you will take in the next two weeks?”*. This enables the lecturer to verify if students are outlining a plan according to what is expected for the upcoming project phase or deviating from it and may recommend SCRL strategies accordingly (Regulation of cognition).

Example 5 – Motivational or clarification doubts

The level of confidence that the student has in relation to the work developed is an indicator that allows the lecturer to perceive whether the student's confidence (high or low) matches its project status, comparing it to his/her own evaluation. In this example, the answers to the question *“What level of confidence do you feel about the operation of the code of the demonstration application, considering the use of interfaces between components as required?”*, exposed that most of students placed their confidence at a “Regular” level (figure 4).

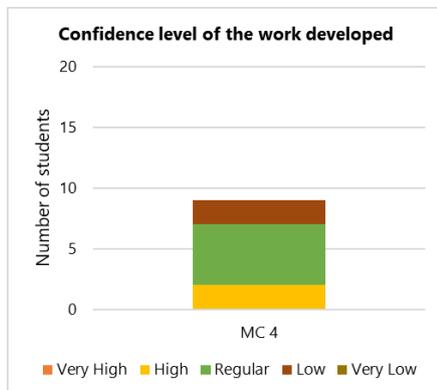


Figure 4: Response of LDS students for the 2019/2020 academic year to the question *“What level of confidence do you feel about the operation of the code of the demonstration application, considering the use of interfaces between components as required?”*.

The lecturer may elect to prioritize analysis of student who expressed a “Very Low” or “Low” level of confidence on this aspect. The “why” follow-up question may enable understanding the reasons and allow the lecturer to intervene accordingly. For instance, if the project work matches expectations, perhaps motivational or confidence-building feedback is necessary, e.g.: *“I went back and lowered the level. I still don't understand how the example code works (...). I haven't gotten past the classic [approaches] yet.”* S44, May 10, 2020.

Example 6 - Clarification of assessment criteria

The MC can also enable lecturers to understand whether a student's self-assessment is similar or different from the lecturer's assessment. If the student's self-assessment is very different from the lecturer's, this awareness may originate, for instance, feedback reminding or clarifying the assessment criteria. Comparing the students' confidence level with their self-assessment level may enable the lecturer to focus on discrepant situations, such as someone who has a “Low” level of confidence about the work developed, but self-assessed as “High”. For example (table 2).

The lecturer can thus proceed, and possibly explore the reason for this imbalance (regular confidence on a very high self-evaluation), and act in accordance with what is expected for that phase (Knowledge of cognition).

Table 2: Comparison between the student's confidence level and self-assessment regarding an MC.

Student	Confidence level	Why?	Self-evaluation	Why?
S1	Regular	"I understood the concept of how to implement error handling in the MVC model. I think I could have implemented a more adequate treatment, which I intend to do in the next steps."	Very High	"My demo application conforms to the MVC style and is easily adaptable to next steps."

Example 7 – Improvement for the next editions of the course:

The MC also allow the lecturer to visualize the evolution of the class, in each of the dimensions, verifying which are the critical phases in which he/she will have to act. For example, the lecturer may perceive a reduction in the students' answering of the MC, along with a predominance of students' perceptions of their learning evolution as "Regular". This may anticipate shortcomings that would only be exposed upon later project delivery and enable pre-emptive action. Also, the lecturer may be able to identify phases where the class have felt difficulties, by detecting sudden changes in the responses – this may expose issues with the syllabus, the pedagogical planning, or other transversal problems (figure 5).

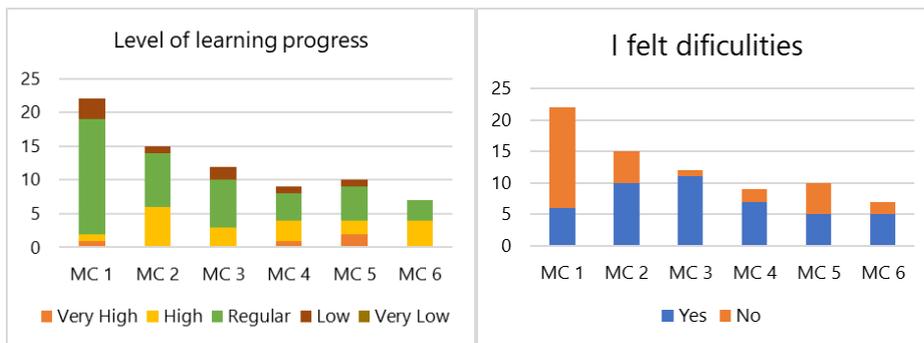


Figure 5: Example of how the MC type1 offer an overview of what happened in the class throughout the course.

The lecturer, when noticing these trends in the answers to the MC, may check for correlations with dropout outcomes (remembering that in Distance Learning dropout rates tend to be high) and intervene. Not just improving the planning/pedagogy in subsequent years, but for the ongoing year, if detected early enough. For instance, acting in a motivational manner, or exploring project development status throughout the class and provide ways to maintain student interest or recover shortcomings. If instead of overall lowering of response rates it is rather a matter of specific students not wanting to address specific MC, the lecturer could try to understand why.

5 Conclusions and final thoughts

The Metacognitive Challenges (MC) emerge as a strategy with the potential for the teaching staff to monitor students' metacognitive learning processes, allowing lecturers to focus their class analysis and feedback effort, and intervene adequately (regulation of cognition and knowledge of cognition) including: 1) Motivational interventions; 2) Recommendations for adopting learning self-regulation and co-regulation strategies; 3) Clarification of doubts due to errors of interpretation, reasoning or resolution; 4) Clarification of assessment criteria; 5) Correction of content or task specification mistakes and/or aspects for pedagogical improvement in subsequent editions of the course (self-reflection of the teacher on his/her pedagogical practices); 6) Understand students' difficulties and help overcome them; 7) Clarification of aspects related to the syllabus and concepts that may be misunderstood.

The awareness of lecturers allows them to make decisions that are critical to the student's learning success. However, analysing MC requires a high amount of effort, so good planning and time management is recommended. Future work will focus on the evaluation of the use of MC by teachers as a form of intervention, verifying their effects on the student's learning process. It is important to develop technological solutions that allow teachers to analyse the contents of MC efficiently and effectively.

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PAEE/ALE'2022 Hands-on sessions

Submissions accepted for the PAEE/ALE'2022 hands-on sessions.

Do we, as educators, have to be neutral in our classroom?

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Abstract

Using controversial issues in classroom can provide interesting learning opportunities. Having to face such situations can make students being aware about how technical decisions can be biased by underlying personal values.

In this hands-on session attendees will face the question about the convenience, or not, of maintaining neutrality in front of our students when including values and ethics in engineering.

Keywords: Politics and Education; Ethics and Values in Engineering Education; Promoting Global Awareness.

1 Introduction

The underlying idea of this hands-on session is well described by the topic of the conference, planting the seed: *promoting engineers with global awareness*, which can be understood as a statement of intent. If we take a picture of the global situation, this global awareness we try to seed in our students implies much more than technical contents.

If we are aware of the social implications of engineering, any decision-making process can be extremely complicated. As stated in the call for papers, *'What we do as engineers and why we do it, is based on our underlying values. However, rarely in engineering education is any consideration taken of our values, what they are and where they come from'* (Nahar and Baillie, 2009). In this sense, when introducing ethics in engineering in our courses we need to understand how our own values are affecting our decisions. From what perspective should we approach this issue?

In the session attendees will face the question about the convenience, or not, of maintaining neutrality in front of our students when including values and ethics in engineering.

This is, without doubt, a controversial topic. Making a fast search on the Internet, you can find teaching professionals with three main points of view, against neutrality, pro neutrality or making it content dependant (left, right and mid sections in figure 1). In short, the answers would be 'yes', 'no' or 'it depends'.



Figure 1. Screenshot of some Internet posts reflecting the three main positions about the topic.

The session will be organized (among others) around the following questions:

- Is neutrality the most polite position?
- Can (or must) we share our political position in the classroom?
- Can we include ethics and values from a neutral position?

- Do we have to show a political position based on the values of our institution?
- Can role-play be an instrument to include political positions without making it personal?
- How to consider the effect of individual personality (introvert - extrovert)?
- What will happen with students not aligned with our opinion?

2 Activities

The main tasks will be performed in small groups. The session will be organized as follows:

- Topic presentation.
- Warm-up activity.
- Group activities (debates / role-play).
- Discussion.
- Conclusion.

3 Expected results

As the session topic does not have an answer, we will try to explore our own starting position and see if it changes or not at the end. We will be expecting to have enriching debates.

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Game-based Learning vs Gamification: A Hands-On

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Abstract

An example of gamification is a contest where students get points for solving the usual exercises of the subject matter. An example of game-based learning is an escape room where students get involved in studying and solving subject matter problems to get the required hints to continue the game. In this sense, game-based learning is an instance of problem-based learning. We propose a hand-on session where participants will get engaged into: first, a gamification activity; and later a game-based learning (GBL) activity. They will be encouraged to notice the differences and make a distinction between them. Afterwards, participants will be required to design a simple escape room situation involving problems for their own courses.

Keywords: Active Learning; Engineering Education; Project Approaches; Game-based Learning; Gamification.

1 Introduction

Gamification has gained popularity in the last years, it is used in primary and secondary schools, as well as in companies and also at the university (Call, 2021). Along with this growth in popularity the number of available computer tools that facilitate the implementation of quizzes, competitions, simulations, WebQuests etc. has also grown.

Play engages students and enhances learning, however not all sorts of games are equally fruitful. As in (Dave Eng, 2019), we make the distinction between gamification and Game-based learning (GBL). An example of gamification is a contest where students get points for solving the usual exercises of the subject matter. An example of game-based learning is an escape room where students get involved in studying and solving subject matter problems to get the required hints to continue the game. In this sense, game-based learning is an instance of problem-based learning as it complies with the characteristics of PBL (Graaff, E. 2003).

The work presented here has been designed as a part of a Teaching Innovation Project to introduce Game Based Learning (GBL) into first year subjects with the aim of fostering (cooperative) learning, engaging students, and providing a positive social dimension. It is an interdisciplinary project that involves 3 different schools of Engineering education in our University where GBL has been introduced in 4 different subjects.

Our goal is to design games from which the students cannot escape without learning (Bofill 2007). As McGonigal proposes (McGonigal 2011), an escape room seeks to have an epic mission, a clear goal, immediate feedback, another chance to prove it and a positive social dimension.

From a general point of view, we can say that learning takes place in five stages [Bofill, 2007]. Namely: motivation, information retrieval, understanding, application (or practice) and feed-back. As we will see, GBL, reinforces the autonomous realization of each of these stages. Figure 1 shows a screenshot of the Escape Room that will be used in the workshop: A bridge over the river Splash



Figure 1. Screenshot of our escape room: a bridge over the river splash.

2 Activities

In the hands-on session we will ask the participants to work in teams and we will need a computer or laptop to be available for each team.

- First participants will engage in a gamification activity: they will be required to solve a simple questionnaire, and we will monitor their progress using Socrative tool (socrative.com).
- Second we will ask them to participate in a game-based learning activity, an escape room implemented with genially <https://genial.ly/es/> where they will be required to solve simple computer programming exercises to obtain the keywords to progress on the game and exit the escape room. Notice that we do not expect the participants to know computer programming so they will be allowed to use other means (aka. cheating) like google to provide the answers to the riddles. The students however are required to write the programs to solve the questions.
- Third, we will ask participants to reflect on both experiences and notice the difference between gamification (the first) and GBL (the second).
- Fourth, participants will be invited to design a simple escape room situation involving problems for their own courses.
- Finally we will end the session with an open debate, where we may discuss topics such as: evaluation, comparing game-based learning versus gamification strategies, strategies and tools for applying such gaming techniques in the classroom and online. The debate will be aimed to formulate conclusions and get feedback and ideas to improve our game-based activities.

Inspirational questions to open debate:

- Which sort of gaming experience provided higher motivation?
- What differences can you see between gamification and GBL?
- Think of ways to introduce GBL into your subject
- Regarding the quality or level of understanding, which experience do you think provides a deeper level?

3 Expected results

We expect a fruitful discussion and each participant should go home with some ideas on how to introduce GBL into his subjects. We also aim to have fun and spread the joy of learning through play. We will evaluate the activity with a survey (using the same Socrative tool).

4 Instructions for Participants

The activity is open to everybody who has an interest on the topic. Participants will be required to bring a laptop and a set of earphones, or otherwise it should be made available a computer per team to be able to carry on the session.

They should also come with an open mind and willing to have fun.

5 Acknowledgement

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Engineers working as a team: socio-emotional and intercultural skills for multicultural environments

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Abstract

This workshop consists of an activity that aims to help engineering students to develop socio-emotional and intercultural skills. Through a usual situation for engineers at the beginning of their career, the participant will have the opportunity to experience a situation in which it will be necessary to work as a team, communicate, negotiate, and deal with colleagues of different nationalities.

Keywords: Teamwork skills; Socioemotional and intercultural skills; Engineering Education; Active Learning.

1 Introduction

Engineering students need more than technical knowledge to face the demands of the 21st century (Downey et al., 2006; Passow, 2012). They also need to develop lifelong learning skills, such as socio-emotional and intercultural skills. Socio-emotional skills will enable future engineers to understand the social, moral and human values of a society. This will help them to work as a team, negotiate, manage, empathize, and deal better with colleagues, customers and the general public. Developing cross-cultural skills will provide the future engineer with the competence needed to work on complex global projects, immigrate to find work, collaborate and compete with colleagues of other nationalities, and work for international companies. Engineering schools are exploring ways to support and develop socio-emotional and intercultural competences in students. However, to date, studies on this subject are not as abundant as one would like (Ndubuisi et al., 2020).

Seat, Parsons & Poppen (2001) brought that there is no secret that the quality of interpersonal, communication, and teaming skills in engineering graduates—termed *performance skills*—is of concern to both industry employers and engineering educators. These skills include communication abilities, interpersonal interaction, conflict mediation, team performance, understanding of technical culture, and sensitivity toward diverse populations due to race, ethnicity, gender, and socio-economic standing.

Besides learning how to work in teams, engineering students need to learn how to establish a collaborative culture in their future workplace and how to deal/communicate/negotiate with people from different countries and cultures (Josefsson, 2010; Rico-García & Fielden Burns, 2019).

2 Activities

The activities in this workshop are:

- (i) Getting to know each other.
- (ii) Dividing the participants in pairs.
- (iii) Developing the activity:

Part 1: a large company sends two engineers (one from country A and one from country B) to work on the construction of two bridges and an underwater tunnel between Cardiff and Weston-super-Mare in the United Kingdom. For that, a two-bedroom apartment will be made available where they will live for a year. The apartments have basic items, but most of the furniture is not available. Each of the engineers will receive a sum of 2000 euros to equip and furnish the apartment, considering their personal and cultural characteristics.

Part 2: upon arriving in the UK, the two engineers are informed that there has been a logistical problem in the allocation of the apartments, and they will have to share the apartment with two more engineers from country C and country D. Therefore, they will have to divide themselves into pairs that will occupy each dormitory and will have to redo the shopping list, because due to this relocation, each of the four engineers will receive only 1200 euros.

- (iv) Presenting the results obtained by the different teams.
- (v) Reflecting on the results obtained by the different teams.

3 Material needed for the workshop

Each participant must bring their notebook to the workshop. The workshop organizers will provide office supplies.

4 Expected results

By the end of this workshop, we expect that the participants can recognize that besides having skills to work in teams, future engineers need to be prepared to share a living space with co-workers, negotiate, manage, empathize and deal better with colleagues, work on complex global projects, immigrate to find work, collaborate and compete with colleagues of other nationalities, and work for international companies, among other skills that are important for academic and professional life.

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Problem Based Learning – Making Blended Learning work!

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Abstract

The Covid-19 situation forced many educational institutions to change their educational offer into either blended or fully online formats. While classical lectures and other “passive learning” methods can be quite easily adapted to this new format – given that technology and connectivity is in place – it is more challenging when it comes to various active learning methods such as Problem Based Learning. However, for Problem Based Learning, the blended format also has strong potentials: It can open for more flexible ways of working together across physical distances, and as such serve as an enabler for projects based on international collaboration, and it can generally increase the flexibility and accessibility of education. This workshop will focus on how Problem Based Learning projects can be carried out in a blended setting, and walk through the different phases: Problem identification, group formation, group collaboration, supervision, and assessment. For each phase there will be a short introductory presentation, followed by group discussions on challenges in carrying out this phase in a blended setting, and how these challenges can be overcome.

Keywords: Active Learning; Engineering Education; Project Approaches.

1 Introduction

Problem Based Learning (PBL) is known as an efficient and motivating way of learning in engineering education that not only provide the learners with technical skills, but also supports the learning of competences related to teamwork, project management and other transversal skills (Kolmos et al., 2004). In the recent years, various efforts have been taken to also explore international collaboration, both at a European level with projects such as EPIC (Pedersen et al., 2019) and COLIBRI (Pedersen et al., 2016), and at global levels e.g. (Britze et al., 2021). While these projects are all based on blended learning – with a large virtual component due to the physical distances – one common learning point is the importance of the physical learning activities and design hereof: Kick-off seminars, possibly with added extra mobilities, are important for both content discussions and for establishing good dynamics within and between student groups.

With the lockdowns during Covid-19, remote and virtual learning spaces became the “new normal”, at least for a while. This added a completely different scale to the experiments with PBL and virtual collaboration, where it was necessary to carry out all phases of the PBL projects virtually. With the improvement of the Covid-19 situation most universities are back to physical teaching. However, with the experiences from extended periods of fully online learning activities in mind, the good question is: How can we use these experiences to improve the blended learning experiences even after Covid? It is interesting to investigate how it can support projects which by nature need virtual components (such as international projects), but also how it can be used in other settings, for example to make education more flexible and accessible.

In this workshop, the focus will specifically focus on the blended settings, including the selection of virtual vs. physical components. The workshop will cover the following phases of a student project:

- Identifying problems in collaboration with internal and external stakeholders.
- Group formation, where students form groups and choose problems.
- Group collaboration.
- Supervision, including supervisor meetings.
- Assessment and examinations.

The purpose of the workshop is to share experiences from both the author and other participants, and based on these enable the participants to design blended learning settings for PBL projects, with a particular focus on how to choose and design the virtual and physical components, to reflect on how to benefit from the

opportunities offered by the blended settings, and how to identify and deal with some of the most challenging aspects of blended learning – all in all, enabling the participants to design blended learning that works. The workshop is related to the conference theme of Active Learning and ICT support, yet also addressing the theme of Innovative experiences in engineering education.

2 Activities

The session will be hands-on, and the participants will mainly work in smaller groups of 3-4 people. The focus will be on the phases described above (identifying problems, group formation, group collaboration, supervision, assessment).

After a 5-minute icebreaker in the groups, for each of the five phases the following is done:

- 2-minute introduction to the phase in plenum, including a short review of existing experiences.
- 8 minutes discussion in groups, where the participants sketch 1-2 ways to carry out the phase in a blended setting. This is documented in terms of 3 key-words per group per question, submitted on a Padlet.

Each group will eventually select the keyword, which is found to describe the most challenging aspect.

Eventually there will be 25 minutes where groups are paired (so 6-8 people together) and discussing these aspects with each other. During the last 10 minutes the facilitator will bring up highlights from the discussions in each group.

The participants are requested to bring laptop, smartphone, or tablet in order to be able to contribute to the Padlet documentation.

3 Expected results

At the end of the workshop, the participants will be better prepared to facilitate PBL projects in blended settings, and the Padlet printouts will serve as concrete sources of inspiration. The identification of challenges can also support further research and experiments in the field.

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Haakins: 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 180 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, programming, 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

With our societies becoming increasingly digitalised, we are also becoming more exposed and vulnerable to cyber-attacks. According to FBI's Internet Crime Complaint Center, 2021 gave new records both in terms of number of cases (847,376) and the total losses (\$ 6.9 billion). These numbers have been consistently increasing during the last years – in 2017, the total number of cases was 301,580, and the losses \$1.4 billion (FBI, 2021).

One of the main problems for companies and societies is the lack of cyber security professionals. According to the (ISC)2 2021 Cybersecurity Workforce Study (ISC2, 2021) there is – despite of many efforts across the global – a workforce gap of 2.72 million people.

One way to attract more young people into working with cyber security is to introduce cyber security at all levels in the educational system is to use cyber security training platforms, which can increase awareness by providing fun and interesting hands-on challenges – often with an element of gamification (Kjorveziroski et al., 2020). One such platform is the Haaukins platform developed by Aalborg University (Panum et al, 2019). Haaukins makes it possible for teachers to setup virtual labs in a highly automated fashion, and in a way that is easily accessible for both students and teachers as everything runs in a browser and no special software is required. The teacher simply selects the number of labs, the relevant challenges for that class – and then students can sign up and compete for points among other students in the same class. The gamification is supported by leader boards and scoreboards, so progression can be tracked by all participants throughout the session. However, as the uptake of Haaukins is increasing, and as more teachers with different backgrounds – sometimes with little experience with cyber security – it is becoming even more important that the system is not only technically user friendly, but also that the pedagogical approaches are clear, and that both teachers and students are supported by the platform together with other online resources (Menecozzi et al, 2021).

This pedagogical challenge is also the starting point for this hands-on workshop, where we will explore and discuss the use of Haaukins with an emphasis on good pedagogical practices.

2 Activities

The session is divided in two parts, each expected to last around 45 minutes.

The first part is a presentation of the Haaukins platform, where the participants also get the chance to solve challenges and, in this way, get a good understanding of how the platform works. Participation requires no previous experience with computers, programming, or cyber security. The first part contains the following elements:

- Presentation of the Haaukins platform (5 minutes)
- Demonstration and hands-on work on two challenges, organised like a typical training session with (1) introduction to the concept, (2) introduction to the challenge, (3) participants working two and two on the challenge, (4) demonstration of the solution. 20 minutes is allocated to each challenge.
- More challenges will be made available for the participants, so in case there are participants with domain knowledge, they can move faster, and all participants have the possibility to try out more challenges after the session.

The second part is a discussion session on how the platform can be integrated in learning facilities. The participants are divided into groups, where each group discuss one of the following topics:

- How to integrate hands-on training into cyber security teaching in the best way?
- How can hands-on training be integrated into cyber security teaching in a curriculum, in different programs with students from different backgrounds?
- How to enable the teachers to use the platform, given often limited time constraints?
- How can Haaukins be used in promoting more diversity among cyber security students, e.g. attracting more women to the field?

For the second part, the groups will have 30 minutes to discuss their topic, and then no more than 3 minutes per group to present the most interesting findings. The findings for each group will be documented in a Padlet.

The participants are requested to bring a laptop to be able to do the challenges, but no special software is required. The laptop will also be used for documenting the group discussions in the Padlet

3 Expected results

There are two main results of the workshop:

- The participants will be prepared to facilitate cyber security trainings using the Haaukins platform.
- We will generate ideas and knowledge about how to improve learning, teaching, and training within cyber security, including achieving more diversity and better gender balance in the field.

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