PROJECT APPROACHES IN ENGINEERING EDUCATION

The Development of Competences for Engineers within a Global Context

PAEE/ALE'2021

International Conference on Active Learning in Engineering Education

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PROJECT APPROACHES IN ENGINEERING EDUCATION

ALE

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PROJECT APPROACHES IN ENGINEERING EDUCATION

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

This is a digital edition.

WELCOME TO PAEE/ALE'2021

Dear Participants,

Welcome to the International Conference on Active Learning in Engineering Education (PAEE/ALE'2021). This is the sixth collaboration of the International Symposium on Project Approaches in Engineering Education (PAEE) and Active Learning in Engineering Education Workshop (ALE) and for the second time, PAEE/ALE will be carried out in hybrid format, which offers a great opportunity for people from all over the world to attend the conference.

The theme of the conference is "The Development of Competences for Engineers within a Global Context". The world needs more creative, flexible and entrepreneurial young people who are prepared for the challenges of today's ever changing work environment. It is understood that the engineering student needs, in addition to technical knowledge, to develop procedural, attitudinal and socioemotional skills. To this end, it is necessary to design curricula that consider the adoption of more modern pedagogical strategies and methods that are more appropriate to the new global reality, that is, strategies and methods that enable students to be the main actor in their learning process.

The COVID-19 pandemic brought to light the urgent need for the use of information technologies in Engineering Education and the need for initial and continuing training for engineering teachers both for active learning strategies and methods, for the use of technological resources and adequate assessment tools. The teacher needs to understand that, in active learning environments that are designed for students to develop competences, he/she no longer has the main and central role in the generation and dissemination of content, to adopt the role of content curator, mediator and tutor.

Renowned keynote speakers from the Engineering Education area will be present in this PAEE/ALE edition sharing their experience with the participants. May the International Conference on Active Learning in Engineering Education (PAEE/ALE'2021) 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 developing competences.

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.

Rui M. Lima & Valquíria Villas-Boas

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PAEE/ALE’2021 Invited Speakers

PAEE/ALE’2021 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:

- Eric Mazur (Harvard University, USA)
- Maura Borrego (University of Texas at Austin, USA)
- John E. Mitchell (University College London, UK)
- Manuel João Costa (University of Minho, Portugal)

Eric Mazur

Harvard University, USA

Title of the keynote - Getting Every Student Ready for Every Class

Short bio

Eric Mazur is the Balkanski Professor of Physics and Applied Physics and Area Chair for Applied Physics at Harvard University and Member of the Faculty of Education at the Harvard Graduate School of Education. He is also the Past President of the Optical Society, the leading professional association in optics and photonics, home to accomplished science, engineering, and business leaders from all over the world. Mazur is a prominent physicist known for his contributions in nanophotonics, an internationally recognized educational innovator, and a sought after speaker. In education he is widely known for his work on Peer Instruction, an interactive teaching method aimed at engaging students in the classroom and beyond. In 2014 Mazur became the inaugural recipient of the Minerva Prize for Advancements in Higher Education. He has received many awards for his work in physics and in education and has founded several successful companies. Mazur has been widely published in peer-reviewed journals and holds numerous patents. He has also written extensively on education and is the author of Peer Instruction: A User's Manual (Prentice Hall, 1997), a book that explains how to teach large lecture classes interactively, and of the Principles and Practice of Physics (Pearson, 2015), a book that presents a groundbreaking new approach to teaching introductory calculus-based physics. Mazur is a leading speaker on optics and on education. His motivational lectures on interactive teaching, educational technology, and assessment have inspired people around the world to change their approach to teaching.

Maura Borrego

University of Texas at Austin, USA

Title of the keynote - Reducing student resistance to active learning

Short bio

Maura Borrego is Director of the Center for Engineering Education and Professor of Mechanical Engineering and STEM Education at the University of Texas at Austin, USA. Dr. Borrego is a Fellow of the American Society for Engineering Education and a Senior Associate Editor for Journal of Women and Minorities in Science and Engineering. She previously served on the board of the American Society for Engineering Education. Her research awards include U.S. Presidential Early Career Award for Scientists and Engineers (PECASE), a U.S. National Science Foundation CAREER award, and two outstanding publication awards from the American Educational Research Association for her journal articles. All of Dr. Borrego’s degrees are in Materials Science and Engineering. Her M.S. and Ph.D. are from Stanford University, U.S.A, and her B.S. is from University of Wisconsin-Madison, USA.

John E. Mitchell

University College London (UCL), London, UK

Title of the keynote - The UCL Integrated Engineering Programme: Implementing a project-based curriculum in a research-intensive university

Short bio

John E. Mitchell is Professor of Communications Systems Engineering in the UCL Department of Electronic and Electrical Engineering, Vice-Dean Education in the UCL Faculty of Engineering Sciences and Co-director of the UCL Centre for Engineering Education. Between 2012 and 2016 he was on secondment to the UCL Engineering Sciences Faculty office, where he led the introduction of the Integrated Engineering Programme (IEP). The team that led this major revision of the curriculum across the engineering faculty has recently been awarded the HEA Collaborative Award for Teaching Excellence (CATE). In 2009, he was awarded the UCL Provost's award for teaching and has published on curriculum development with engineering education. Professor Mitchell is a Chartered Engineer, Fellow of the Institution of Engineering and Technology (IET), a Senior Member of the Institute of Electrical and Electronics Engineers (IEEE), Member of the Board of Directors of the European Society for Engineering Education and Principal Fellow of the Higher Education Academy. He is currently Editor-in-Chief of the IEEE Transactions on Education.

Manuel João Costa

University of Minho, Portugal

Title of the keynote - Teacher Professional Development in Higher Education - engaging students

Short bio

Manuel João Costa is Associate Professor at the School of Medicine. Pro-Rector for Educational Innovation and Student Affairs at the University of Minho and coordinator of the University of Minho's center for innovation and development to teaching and learning (IDEA-UMinho. He is appointed member to education committees of the International Union of Biochemistry and Molecular Biology, Federation of European Biochemical Societies and delegate at the faculty development committee of the Association for Medical Education in Europe. Served as associate editor for international journals, including PLOS One and BMC Medical Education and is editorial board member of the journal Biochemistry and Molecular Biology Education. Researcher ID: C-3900-2009; ORCID: 0000-0001-5255-4257.

PAEE/ALE'2021 Programme

	7 July (Wed) (Hybrid)	8 July (Thu) (Hybrid)	9 July (Fri) (Full Online)
9.00 - 9.30	**Opening** (local+online)		
9.30 - 11.00	**Hands-on Sessions** HO.1 (local) HO.2 (online)	**Students Papers Sessions** ST.1 (*5 presentations*) (local) ST.2 (*5 presentations*) (online) ST.3 (*6 presentations*) (online)	**Industry Panel** (online)
11.00 - 11.30	Coffee Break	Coffee Break	Break
11.30 - 13.00	**Keynote Speaker** (local+online) **Manuel João** *Teacher Professional Development in Higher Education – engaging students*	**Hands-on Sessions** HO.3 (local) HO.4 (online) HO.5 (online)	**Keynote Speaker** (online) **John Mitchell** *The UCL Integrated Engineering Programme: Implementing a project-based curriculum in a research-intensive university*
13.00 - 14.30	Lunch	Lunch	Closing
14.30 - 16.00	**Keynote Speaker / Workshop** (online) **Eric Mazur** *Getting Every Student Ready for Every Class*	**Paper Sessions** PS.5 (*5 presentations*) (local) PS.6 (*5 presentations*) (online) PS.7 (*5 presentations*) (online) PS.8 (6 presentations) (online)	
16.00 - 16.30	Coffee Break	Coffee Break	
16.30 - 18.00	**Paper Sessions** PS.1 (*5 presentations*) (local) PS.2 (*5 presentations*) (online) PS.3 (*5 presentations*) (online) PS.4 (5 presentations) (online)	**Keynote Speaker** (online) **Maura Borrego** *Reducing student resistance to active learning*	
18.00 - 19.00	**PAEE/ALE Challenge (fun online interactive activity)**		
19.30 - 21.30		**Conference Dinner**	

PAEE/ALE'2020 Paper Sessions, Hands-On Sessions and Students Sessions

Day 1

Day 1	7 July, Wednesday (*local + online*)			
09.00 09.30	**Opening** (*local + online*)			
09.30 11.00	**Hands-on Session:** HO.1 (*local*) **Jens Myrup Pedersen** *Problem Based Learning in the Digital Age*		**Hands-on Session:** HO.2 (*online*) **Miguel Romá** *Collaborative Annotations in times of Physical Distancing*	
11.00 11.30	Coffee Break			
11.30 13.00	**Keynote Speaker** (*local + online*) **Manuel João Costa** *Teacher Professional Development in Higher Education – Engaging Students*			
13.00 14.30	Lunch			
14.30 16.00	**Keynote Speaker / Workshop** (*online*) **Eric Mazur** *Getting Every Student Ready for Every Class*			
16.00 16.30	Coffee Break			
16.30 18.00	**Paper Session:** PS.1 (*local*) **Session Chair:** Valquíria Villas-Boas ------------------------------------ 77 - *Science Communication in Bioengineering and Biotechnology: active and collaborative learning project* (Patrícia Neves, Tatiana Vilaça) ------------------------------------ 76 - *Exploring blended learning tools to transform a laboratory course unit in engineering: challenges, setbacks and rewards* (Tatiana Vilaça) ------------------------------------ 60 - *A problem-based learning experience in engineering education* (Valquíria Villas-Boas) ------------------------------------ 68 - *How to engage engineering students to Physics: A case report of an Introductory Physics course taught in the first year of an Engineering programme* (Cacilda Moura) ------------------------------------ 38 - *An innovative approach to computer mathematics teaching in a large engineering class* (Isabel Espírito Santo) ------------------------------------	**Paper Session:** PS.2 (*online*) **Session Chair:** Rui Sousa ------------------------------------ 55 - *Production of a Virtual event on Quality Management and Collaborative International Projects using Scrum as a Project Management Methodology* (Thiago Lima) ------------------------------------ 18 - *Setbacks of the Development of a Concept Inventory for Scrum: Contributions from the Item Response Theory* (Rui Lima and Walter Nagai) ------------------------------------ 70 - *Characterization of the operators training process at an industrial company* (Rui Sousa) ------------------------------------ 71 - *Industrial Training Qualitative Evaluation with Fuzzy Logic and an Experience Classification Method* (Rui Sousa) ------------------------------------ 58 - *The perception of students from a higher education institution regarding the importance of education in OSH subjects during COVID Pandemic* (Nelson Costa) ------------------------------------	**Paper Session:** PS.3 (*online*) **Session Chair:** José Rodrigues ------------------------------------ 4 - *Management of digital transformation of educational technology: key elements* (Natalia Vatolkina) ------------------------------------ 5 - *E-learning development strategy of the university: comparative study* (Natalia Vatolkina) ------------------------------------ 15 - *Virtualizing project-based learning: an abrupt adaptation of active learning due to the covid-19 pandemic with promising outcomes* (Cristiano Reis) ------------------------------------ 25 - *Exploring a BPMS system for learning production management with simulation of manufacturing scenarios* (José Rodrigues) ------------------------------------ 48 - *Game-Based Learning in a production engineering course in Brazil* (José Rodrigues) ------------------------------------	**Paper Session:** PS.4 (*online*) **Session Chair:** Natascha Janssen ------------------------------------ 1 - *Teacher collaboration in PBL: setting the example for the students* (Anabela Alves) ------------------------------------ 74 - *Teaching innovation: comparison between project-based and traditional learning approaches* (Sanderson Barbalho) ------------------------------------ 23 - *Cases for teaching and learning assessment planning: a study in the perception of teachers and students from two Brazilian universities* (Maria Brito) ------------------------------------ 8 - *The Show Must Go On: Active Online Collaboration during COVID-19 – Mathematics Students Solving Real-World Problems* (Marietjie Havenga, Tertia Jordaan) ------------------------------------ 35 - *Mapping the circular economy context within the curricula in the field of Industrial Engineering - comparative study of selected programs in two Polish universities* (Tomasz Nitkiewicz) ------------------------------------
18.00 19.00	**PAEE/ALE Challenge** **(*fun online interactive activity*)**			

Day 2

Day 2	8 July, Thursday (*local + online*)

09.30 11.00	**Students Paper Session**: ST.1 (*local + online*) **Session Chair**: Sandra Fernandes --- 47 (local) - *Preferred Roles of Industrial Engineering and Management Students - An exploratory European analysis* (Viktoria Heyen, Maria Serodio) --- 78 (local) - *Learning science during summer vacations and its effects on Attitude and Anxiety towards Research* (Violeta Carvalho) --- 12 - *Development and application of a teaching-learning model among EduScrum and active learning methodologies* (Erik Lopes) --- 13 - *Desencrenca: a PBL experience on Project Management education* (Erik Lopes) --- 46 - *CDIO and Biomimicry: a case of study of analysis of the enhanced structural masonry interlock with the nacre interlacing solution* (Roberto Silva)	**Students Paper Session**: ST.2 (*online*) **Session Chair**: Diana Mesquita --- 42 - *Using PBL to design a gamified application prototype: the case of waste picker's children financial education* (Júlia Brito) --- 64 - *Preparation Workshops for Mathematics Olympiads* (Júlia Thomazoni) --- 41 - *Development of an Integration Methodology for project management in an adapted online environment on a PBL discipline* (Júlia Brito) --- 31 - *Influence of Improvisation Education to Teamwork Abilities Based on Competency* (Shogo Takezaki) --- 19 - *Sustainability-focused international PBL project: Rethinking digital education for individuals of low socioeconomic status* (Daniel Britze, Jacob Jensen)	**Students Paper Session**: ST.3 (*online*) **Session Chair**: Anabela Alves --- 9 - *Perception of Professors and Undergraduate Students of Engineering at the University of Brasilia (UnB) on Emergency Remote Learning Period in the context of the Covid-19 Pandemic* (Lahra Schemmer) --- 43 - *Project Based Learning during the COVID-19 Pandemic: Experiment Reports of Initiatives in Computer Engineering* (Victor Hayashi) --- 59 - *Online adaptation strategies for active learning methodologies in STEM education* (Larissa Santos) --- 33 - *A new remote laboratory of a pumping system designed using a low-cost hardware model* (José Carretero)
11.00 11.30	Coffee Break		
11.30 13.00	**Hands-on Session**: HO.3 (*local*) **Miguel Romá**, Montse Farreras, P. Bofill, J. Armengol *Promoting creativity through collaborative assessment*	**Hands-on Session**: HO.4 (*online*) **Montse Farreras**, Pau Bofill, J. Armengol, M. Romá *Plant a seed for the future*	**Hands-on Session**: HO.5 (*online*) **Igor Montagner, Rafael Ferrão**, Andrew Kurauchi *Creating and publishing active learning handouts*
13.00 14.30	Lunch		

14.30 16.00	**Paper Session**: PS.5 (*local*) **Session Chair**: Teresa Monteiro --- 2 - *Online assessment: more student cheating than onsite?* (Anabela Alves) --- 28 - *Development Process of a Rubric for Assessment of Leadership Competences in Project Management Scenarios* (Diana Mesquita, Mariane Souza, Élida Margalho) --- 39 - *Integrating project management and peer assessment: a case for increased teamwork* (Natascha van Hattum-Janssen) --- 34 - *Innovating to improve – an experience in a Computer Engineering programme* (Teresa Monteiro) --- 20 - *Adapting to Online Education through project-based learning in a complex remote zone (Magallanes /Chile)* (Jorge Ortega)	**Paper Session**: PS.6 (*online*) **Session Chair**: Rui Lima --- 65 - *Mechanical Engineering Students Project Based Learning in OUAS* (Ville Isoherranen) --- 67 - *Oamk_Highway – New route for young people towards engineering degree in Northern Finland* (Ville Isoherranen) --- 6 - *Bringing PBL to Education for Sustainable Development: University to Business (U2B) approach* (Tatiana Salimova) --- 40 - *Project-based active learning in a robotic master's degree Subject with covid combined face-to-face and online teaching requirements* (Vicente Morell) --- 32 - *Project-based learning in Robotics subject of a Master's Degree* (Vicente Morell)	**Paper Session**: PS.7 (*online*) **Session Chair**: Sandra Fernandes --- 69 - *Students' perceptions of the use of traditional methods and active learning strategies in the classroom: findings from a case study* (Filomena Lopes, Sandra Fernandes) --- 73 - *Active learning in project management: the life cycle of a virtual scientific colloquium and its impact on students' performance* (Sanderson Barbalho) --- 72 - *Engineering Education Active Learning Maturity Model: a Conceptual Framework* (Humberto Arruda) --- 61 - *Active methodology: the experience of the land regularization commission (CRF-UFPA) in the agents of registry qualification* (Elaine Angelim, Renato das Neves) --- 56 - *Student motivation in the first year of University: findings from the implementation of a PBL project for a real context* (Sandra Fernandes)	**Paper Session**: PS.8 (*online*) **Session Chair**: Nélson Costa --- 24 - *Communication and alignment of expectations in implementing a PBL proposal* (Octavio Neto) --- 22 - *Development of Capstone Integrative Projects as a tool for learning Design and Process Control in Chemical Engineering* (Carlos López) --- 30 - *Risk Assessment of Project Based Learning Failure via Bayesian Belief Networks and Analytical Hierarchy Process – A Literature Review* (José Pereira) --- 17 - *Adapting studio and lab sessions to emergency remote teaching: an analysis of instructor-student interactions* (Rafael Ferrão) --- 49 - *The use of games in a graduation course in an engineering faculty* (José Rodrigues)
16.00 16.30	Coffee Break			
16.30 18.00	**Keynote Speaker** (*online*) **Maura Borrego** *Reducing Student Resistance to Active Learning*			
20.00 22.00	**Conference Dinner**			

Day 3

Day 3	9 July, Friday (*online*)
09.30 11.00	**Industry Panel:** IP.1 (*online*) *Engineering Skills for Industry* **Moderator:** José Dinis-Carvalho *University of Minho* **Participants:** Berta Alonso *Sustainability Department of Inditex* Alain Afonso *Brunswick Portugal* Alberto Bastos *Kaizen Institute Portugal* Jorge Ferreira *IKEA Industry Portugal*
11.00 11.30	Coffee Break
11.30 13.00	**Keynote Speaker** (*online*) **John Mitchell** *The UCL Integrated Engineering Programme*
13.00 13.30	**Closing**

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PAEE/ALE'2021 Submissions

The PAEE/ALE'2021, 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 Engineering of University of Minho, since 2009, and the ALE workshop, which is being organized by the ALE Network, since 2000. PAEE/ALE'2021 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'2021 event is hybrid, with both full online and local on site sessions.

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'2021 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.

The proceedings are published under the Guidelines on Open Access to Scientific Publications and Research Data in Horizon 2020 (http://ec.europa.eu/research/participants/data/ref/h2020/grants_manual/hi/oa_pilot/h2020-hi-oa-pilot-guide_en.pdf): "Open access to scientific publications refers to free of charge online access for any user." The authors retain the copyright of their work.

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The PAEE/ALE editorial board and scientific committee are committed to preventing publication malpractice, do not accept any kind of unethical behaviour, and do not tolerate any kind of plagiarism. Authors, editors, and reviewers are to be committed with good practice of publications and accept to fulfil the duties and responsibilities as set by the COPE Code of Conduct (http://publicationethics.org/resources/code-conduct). Based on these, PAEE/ALE expects authors, editors, and reviewers to be committed to the following general guidelines:

- Editors take decisions on the acceptance of papers and compose and evaluate the proceedings quality.
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- 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.

PAEE/ALE'2021 List of Submissions

PAEE/ALE’2021 Full Papers Submissions

Submissions accepted for the PAEE/ALE’2021 papers sessions in English.

Teacher collaboration in PBL: setting the example for the students

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Abstract

This paper discusses collaboration between teachers in project-based learning (PBL) environments in the engineering context. PBL is a challenging active learning methodology, not only for students but also for teachers. Challenges for teachers include, for example, the need to search for new knowledge demanded by the PBL project theme and the difficulty of aligning their own disciplinary area with interdisciplinary areas in a project. PBL compromises common assumptions of teachers, such as the considerable control over the classroom, reliance on their expert knowledge, predictable programmes to teach, the course assessment, the individual work, among others, whereas, probably, the most challenging aspect of PBL from a teacher perspective is teamwork of the teaching team. Teacher may well feel uncomfortable with sharing knowledge and being exposed and/or assessed by their students and peers. At the same time, PBL requires teachers to think about student achievement and success in first place instead of using more mono-disciplinary course based approach. In this paper, the authors will present evidence through literature review and experience in PBL contexts that such collaboration is highly recommended, if not mandatory, for the PBL success. The paper will also advocate that teacher collaboration is important as an example for students to engage in collaboration.

Keywords: Engineering Education; teachers' collaboration; Project-Based Learning (PBL).

1 Introduction

Collaboration, teamwork and the development of shared tasks has always been a common practice amongst higher education teachers. With the grown interest and implementation of student-centred learning approaches (Gaebel et al., 2018) and multidisciplinary project approaches, especially within the Engineering Education field (Guerra et al., 2017), the opportunity for greater teacher collaboration also arises.

Research on teacher collaboration in Engineering Education reveals a great number of different concepts which refer to this same idea, for example, team teaching, co-teaching and collaborative teaching (Vesikivi et al., 2019). According to these authors, team teaching can be defined as two or more teachers planning, instructing and evaluating the learning of a single group of students; co-teaching refers to two or more teachers instructing a multidisciplinary student team in the same classroom; and, collaborative teaching emphasising teacher collaboration and co-operative teaching is used. However, despite the number of teachers involved and their role in the teaching and learning process, these authors argue that "the definition of team teaching should be based on the pedagogical approach and grounded in learning theory" (Vesikivi et al., 2019).

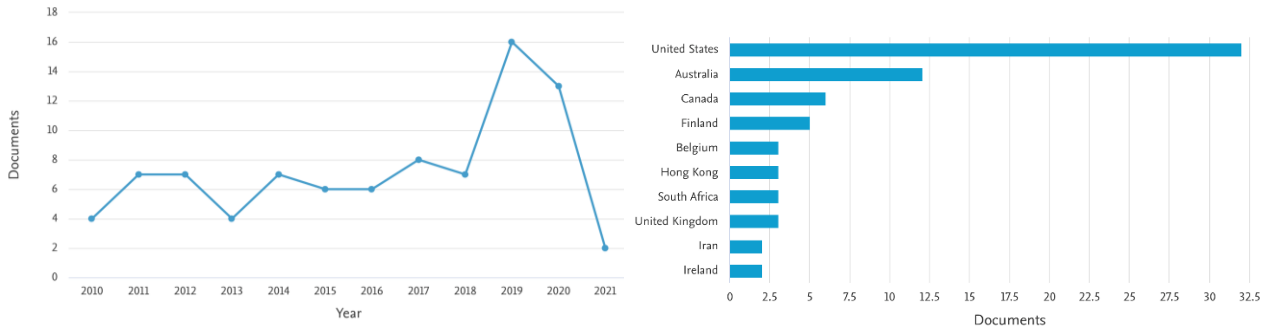
The active learning methodology known as Project-Based Learning (PBL) involves students actively in their own learning. In this context, students, working in teams, must carry out a project to solve a large-scale complex open-ended problem, through a long period of time (Powell & Weenk, 2003). To support this development, teams have the support of their teachers and the knowledge and skills acquired from the courses. This means teachers must plan, work and collaborate with each other and discuss about education issues across boundaries to help teams in this endeavour (Powell, 1999). According to this same author, PBL requires teamwork for tutors, teachers, administrators and integration over the traditional subject boundaries, what could be considered a disadvantage of the PBL.

Having higher education teachers work together seems to have many advantages, but could be rather challenging, if they are not used to do so. The objective of this paper is to explore the difficulties that teachers face by presenting a literature review about the importance of teacher collaboration, its benefits and difficulties on this. Also, the authors illustrate the findings from the literature with experiences from their own learning process as teachers working in teams.

After this brief introduction, section two presents a brief literature review about team teaching in Higher Education. Section three describes the research methodology followed to achieve results. The results are presented and discussed on section four, which is organized based on the overall results and evidence from PBL practitioners' experience. The last section of the paper presents the conclusions and final remarks.

2 Team Teaching in Higher Education

Team teaching is not a phenomenon that is exclusive for engineering education. When analysing 177 publications on team teaching in SCOPUS, of which 117 (66.7%) are articles, 33 (18.6%) are conference papers and 22 are book chapters (12.4%) using ALL ("higher education") AND TITLE-ABS-KEY ("team teaching")) PUBYEAR > 2009 AND (LIMIT-TO (LANGUAGE ,"English")) most are actually from the social sciences, 52.6%, followed by computer science (9.3%) and engineering (9.0%). Figure 1 presents some graphs retrieved from Scopus with number of documents by year and country/territory.



a) b)

Figure 1. Documents found in the search classified by: a) year; b) country/territory

Of the articles, conference papers and book chapters, 87 are focused on team teaching whereas the others have a focus on approaches to teaching, forms of students learning or educational innovation in a broader sense and do not focus specifically on team teaching. When looking at these in more detail, at the 87 papers, the relative number of engineering papers is even lower, 6.1% (Figure 2).

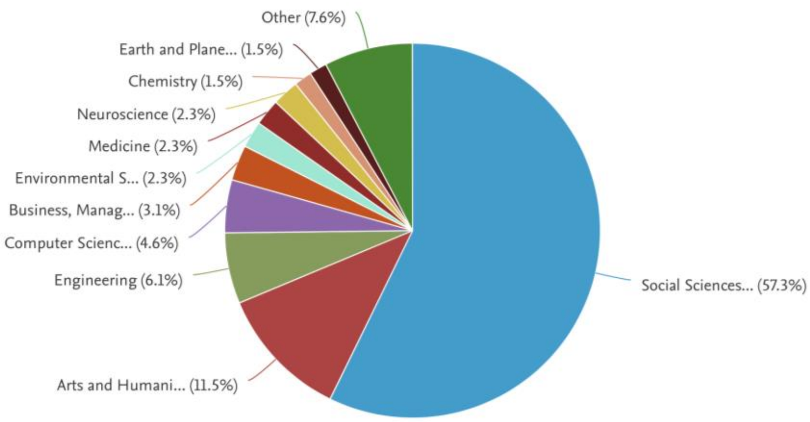


Figure 2. Documents by subject area

A single definition of team teaching was not found, but various authors refer to characteristics of team teaching like Minett-Smith and Davis (2020) who refer to the involvement of two or more teachers, the degree of interaction between the teachers, the resources they share and the interdependence between the teachers.

Liebel, Burden and Heldal (2017) do not provide a single definition either, but refer to the purpose of team teaching, especially in an interdisciplinary context, where team teaching can be used for alignment of course objectives. Their study shows the benefits of team teaching, like providing multiple explanations of the same concepts which can be beneficial for student learning. Benefits are also acknowledged by Jones and Harris (2012), who found that team teaching can be positive for both students and teachers, especially when having uniform purposes and expectations and really working as a team. They also acknowledge the reflection on teaching and assessment that team teaching can encourage, especially when mixing teaching assistants and more experienced teachers. The authors have identified a number of requirements for team teaching to be successful, like continuity in the team, a great deal of mutual trust and the absence of hierarchical relationships within the team.

Vesikivia, Lakkalac, Holvikivid and Muukkonene (2019) also refer to team teaching as the effort of, at least, two teachers and identify a number of challenges to overcome in their study at a Finnish university of applied sciences. Teachers may fear a loss of autonomy when shifting to team teaching and face a lack of time when planning and preparing team teaching efforts. The authors point out that this requires leadership that answers the teacher concern. Team teaching is not always welcomed by every single team member, so institutional support can help to overcome the challenges. Money and Coughlan (2016) show that benefits from a teacher point of view do not necessarily coincide with the benefits as identified by students. The joint effort that can result in a decreased workload for teachers may also result in duplicated and conflicting content for students. In order to find out what the characteristics of team teaching mean for project-based learning, especially in an engineering education context, the publications given above are explored more in detail.

3 Research methodology

This study uses a literature review (Miles & Huberman, 1994), to answer the following questions:

- What does the scientific literature say about teacher collaboration in Project-Based Learning (PBL) in the context of Engineering Education?
- What are the reported benefits and difficulties of its use?
- What does evidence from the experience of PBL practitioners in Engineering Education reveal?

To answer the first two research question, a literature review was developed using the Scopus database. As the theme is the teachers' collaboration in PBL in an Engineering context, the keywords used were related to Engineering education, Team teaching, Teacher collaboration and experience and Project-based Learning and its acronym. The time-frame considered was last decade (since 2010) and sources chosen were journals, conference papers and book chapters. The string used was:

- (ALL ("Engineering education") AND TITLE-ABS-KEY ("Team teaching") OR TITLE-ABS-KEY ("Teachers collaboration") OR TITLE-ABS-KEY ("Teachers experience") AND TITLE-ABS-KEY ("PBL") OR TITLE-ABS-KEY ("Project based learning")) AND PUBYEAR > 2009

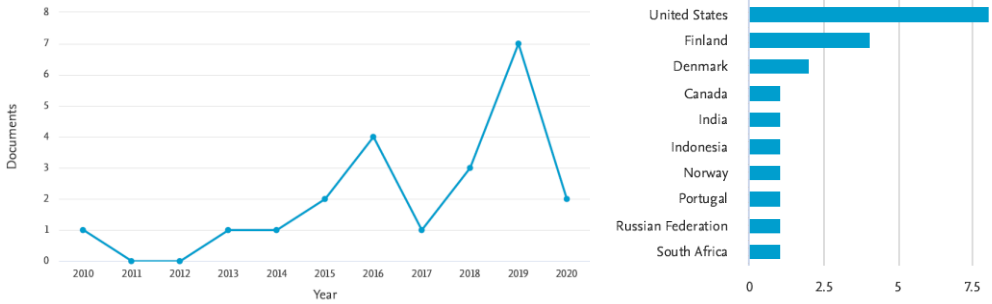
The last research question focuses on evidence based on a literature review of publications of a team of PBL practitioners connected to the first year of the Industrial Engineering and Management (IEM) degree program of the University of Minho, Portugal.

4 Results and discussion

The results of the literature review are presented in two subsections: the first section presents an overall analysis of the bibliometric results retrieved from the Scopus database search, supported by a summary of the main findings based on the studies analysed; the second section, reports on findings based on the literature on the PBL practitioners' own experience.

4.1 Overall results

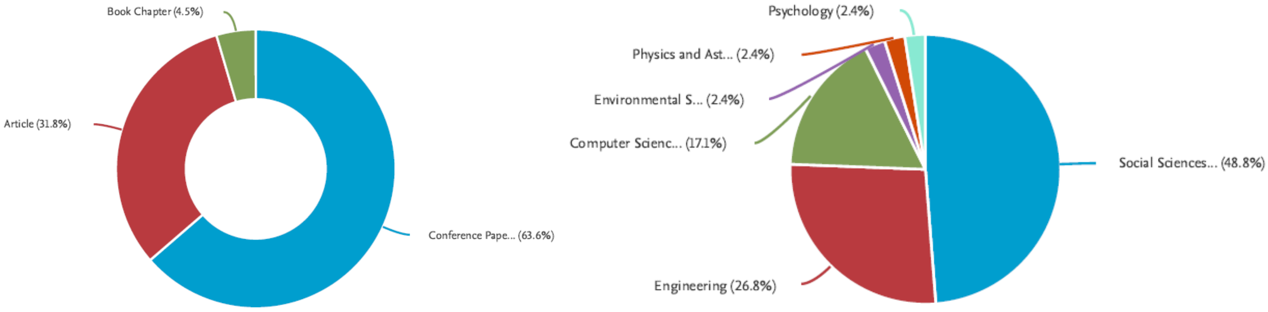
The search in Scopus database produced 22 results, according to the criteria mentioned previously in the methodology section. The main descriptive statistics are reflected in the graphs of Figure 3a) and Figure 3b), that present, respectively, the documents by year and country. The year 2016 and 2019 are the years with more publications. The United Stated and Finland are the countries that lead the publications in this research topic.



a) b)

Figure 3. Documents found in the search classified by: a) year; b) country/territory

Other descriptive statistics are the documents by year and country reflected in the graphs of Figure 4a) and Figure 4b), respectively. Regarding the type of documents published, the majority are part of conference proceedings (63.6%), followed by articles (31.8%) and very few are book chapters (4.5%). The main three subject areas of the publications are Social Sciences (48.8%), Engineering (26.8%) and Computer Sciences (17.1%).



a) b)

Figure 4. Documents founded in the search classified by: a) type; b) subject area

Four papers were excluded from the analysis as one paper was not in English and the full text of three papers was not accessible to the authors, leaving a total of 18 papers to be analysed in detail of which content wise only 9 papers were considered relevant for this study and its research questions. The identification of these papers is provided in Table 1, as well as a short description of the main benefits and difficulties or requests or recommendations of/for teachers' collaboration in PBL context.

Table 1. Benefits and challenges of team teaching according to teachers in PBL experiences

Reference	Features of PBL	
	Benefits	Challenges
(Singh-Pillay, 2020)	• catalyst for pre-service teachers' awareness of their role as agents of change; • collaborative reciprocal learning; • promotes deep thinking about actions; • helps to break stereotypes and allows teachers to belief in the good of others; • positive feelings toward group members and developed collegial relationships; • provided teachers with the skills needed to successfully manage life tasks such as identifying anxieties, labelling emotions, learning in groups, teamwork, awareness of themselves and others	• need for kindness and respect for others, forming relationships, care about others, make good decisions, behave ethically, avoid negative behaviour and overcoming biases; • powerful and transformative nature of PBL, in terms of shifting existing frames of references; • need to be conscious of their roles as agents of change in the communities they worked in.
(Vesikivi et al., 2019)	• opportunity to develop their teaching skills • helps teachers in forming a holistic understanding of subject matters and their relations.	• expense of losing at least some of the teacher autonomy; • requires development of teamwork skills; • loss of autonomy and getting enough time and resources for planning the courses;

	• sharing positive experiences with more reluctant colleagues hopefully encourages the sceptics to try out the new practices and start applying them • when teachers feel the new pedagogical approach and team teaching as rewarding experiences, they feel less concerned or apprehensive towards the educational reform.	• all levels of management are fully behind the idea and actively drive the implementation.
(Baligar et al., 2018)	• learning facilitated by a group of teachers engaged in team teaching; • shared experiences of collaborative approach at various stages of the course evolution, the need for it, the methodologies used and their benefits; • opportunity to explore beyond the disciplinary boundaries and innovate in multi-disciplinary space; • using the experience gained in this course in designing and delivering their courses in their respective departments; • means for providing students with the skills they need; • way to enhance the teacher's own professional development. • getting an opportunity to acquire knowledge from their colleagues belonging to different engineering disciplines and • students receiving feedback from multi-disciplinary perspectives that has led to improvements in their course projects.	• team of faculty members from diverse engineering disciplines; • team of course instructors with different disciplinary background; • practise of team review is followed in all course project reviews; • multi-disciplinary skills in the delivery team of instructors; • team members brought disciplinary knowledge to the team, however, none of the team members had all the competencies and skills required to deliver the course; faculty members needed common understanding of few of the engineering concepts.
(Lutsenko & Lucenko, 2018)	• collaboration with the colleagues from the departments; • provide opportunities for generating ideas for projects of senior engineering students; • teachers from different departments could act as co-facilitators of teams of students or as "customers"; • selection of practically oriented projects, which simultaneously helps to solve pedagogical tasks as contextualisation of the learning process; • encouragement of students to participate in applied design and scientific research; • urgent university organisational tasks, namely, updating and upgrading of laboratory equipment; • use of advanced software allowing to smooth over the lag of technical equipment of Ukrainian engineering departments and, in future, will lead to the full-grown using of emerging technologies.	• teachers need to be ready to be facilitators of student teams; • need to be ready to collaborate with colleagues from other departments as co-facilitators of student projects regardless of project themes; • academic staff must be open to new educational initiatives fostering the implementation of student projects; • difficulties was related to administrative and organisational issues; • workload of teachers from different departments.
(Kodkanon & Pinit, 2018)	• interdisciplinary aspect may be achieved through engagement in project-based learning (PBL); • shared purpose and a framework and guidelines to support teachers' planning; • value of shared decision-making and leadership.	• need for supportive relationships that take into consideration professional and personal issues; • need for open forms of communication that reflect trust, support and respect; • use of social media to support communication and collaboration; • guidelines and rules established in advance by team members.
(Pastor-Mendoza et al., 2018)	• collaboration has helped to students in their Final Degree Projects completion, which has also established a solid collaboration among teachers involved; • collaboration helps the teachers involved to consider modifications in the subjects which they teach to find a better relationship between them within the curricula; • better understand the internal functioning of each one; • useful to involve more professors of other subjects in future projects; • greater the number of teachers involved, the greater the teaching capacity will be for future students who become involved in large-scale projects. • relationship between professors from different areas can also help to reorient some contents of the subjects, to make them more practical and to relate them among themselves; • more attractive and reduce the workload of the students involvement of a larger number of teachers will facilitate the	

	fundraising of the departments, the school and the university.	
(Angelva et al., 2017)	• better learning results and enlarge teachers' know-how. • team-teaching and project based learning (PBL) give • more opportunities to develop industrial cooperation and • student satisfaction factor has raised • total number of credit points students have completed annually. • working together is nice and fun; • makes easier for students to get a professional job after graduation • very instructive; • not bored; • evaluation is worth to complete together in the teacher team if possible; • problem solving together makes it easier; • better completion percentage; • continuous learning;	• developing new curriculum based on PBL and piloting it with different student groups and organizing learning by teacher teams • meaning of the preplanning phase is significant • first time very challenging, repetition makes it easier • everything to the master time table; • planning phase should be started as early as possible • the joint assessment will support your own decisions; • reviews takes some time from the "ancient" one-way; • lectures in resource planning; • the project team of students carry each other; • suitable and accessible space is required for self-oriented project workshops; • physical location of the teacher team as close to workshops as possible; • teacher team located very close to each other to ensure the open communication; • the beginning is always difficult; • new culture requires change in attitude, others are slower than the others; • project management and teamwork skills are required
(Alves et al., 2016)	• a positive view of PBL as a learning approach • student motivation and engagement • better understanding of the application of concepts in real-life situations, as important outcomes of the project for students • highlight the importance of the development of transversal skills by students throughout the project • higher collaborative work between teachers from different departments and schools • projects enable solutions that involve very specific and complex aspects of courses that cannot be explored in classes; • involves teachers in the reflection of their own practices, promoting changes in course design and planning; • recognition of PBL as a suitable methodology to better prepare engineers.	• higher workload for teachers due to formative activities and milestones to give feedback, beyond the classes; • greater difficulties for students who usually have trouble in finding and selecting proper bibliography and need extra support from teachers; • course could require adjustments every year, according to the project; • instruct and better prepare teachers, to provide more resources (e.g. project rooms); • pedagogical support and training (e.g. educational researchers) for teachers to develop active learning activities; • consumes scarce resources of the department; • important to motivate teachers about these new methodologies in order to all be in synergy and reduce the time it takes to 'convince' the disbelievers.
(Vesikivi et al., 2016)	Teacher collaboration was beneficial for students for several reasons: e.g., • students saw one model of professional collaboration, • students received feedback and guidance from multiple teachers, and the • progress of students' project work was better taken into account in teaching when all teachers were aware of the situation and were able to negotiate next steps together on the fly. Team teaching was evaluated mainly as a • positive experience; • very impressive and rewarding for them to finally see "what engineers really do"; • participate in authentic project work practices; • interesting and useful to see other teachers' teaching methods; • discuss about pedagogical problems and solutions together; • learned also more from the students in this new type of modules than in previous courses, because collaboration with them and presence in the classroom was more comprehensive.	1) Organizational setup related concerns: • all teachers on a shared course should participate in the design process from the very beginning to the very end. • very challenging in practice to deploy multidisciplinary courses that involve teachers and students from majors in different organizational units. • hard to find a single person who would be responsible for the guidance of individual students in the course. 2) Training and motivation related concerns: • team teaching was considered to be a major change in the way teaching is conducted; • change in the teacher's way of working. • time allocation for course planning • having multiple teachers on the same course makes planning challenging as even just finding a common time for a design session may prove out to be almost impossible. • mean more work for the same amount of allocated work hours as it is possible that too few hours are allocated for course design. • deterioration of motivation to develop team teaching. 3) Curriculum design related concerns: • free riders among students are always an issue; • effect of team teaching to accumulated competence and knowledge of graduates.

		• common understanding of pedagogical targets is a prerequisite for a successful course; • adoption of new way of teaching will require considerable amount of time. • integration of topics on a team teaching course should be much tighter than was achieved at present. courses may end up being too patchy. 4) Resources related concerns: • lack of resource hours for planning a team teaching course. • planning of such course would take more time and energy than planning a traditional course with one topic area and a single teacher. • scheduling of topics on a course may be challenging as teachers usually have multiple on-going courses; • allocation of adequate time for planning the courses is important; • should be some best practices for creating and empowering the teacher teams. We • should find ways to ensure the quality of learning as well as ways to make the content integrated courses visible and understandable also outside the university; • how much freedom an individual teacher has on a team teaching course is important; • decide related to decisions together and decisions an individual teacher can make alone.

4.2 Evidence from PBL practitioners experience

The authors of this paper have been involved in the implementation of the PBL learning methodology in the first year of Industrial Engineering and Management (IEM) program at the University of Minho for a more than a decade, more precisely since 2004_2005. The project given to the students involves teachers from different schools and departments, mainly from STEM fields (Calculus, Linear Algebra, General Chemistry, Algorithm and Programming, Introduction to IEM and Integrated Project of IEM). In Alves et al. (2019a) more details of this PBL are given. Teachers collaboration was also subject of some papers, namely: van Hattum-Janssen (2011), Fernandes and Flores (2013), Fernandes et al (2014), Alves et al. (2016a) and Alves et al. (2016b) which corroborates most of the results (benefits and difficulties) founded in the literature review. Main difficulties were mainly related to the workload, deeply discussed in Alves et al. (2009) and Alves et al. (2019b), the assessment model definition and the need to adjust the course contents.

In the 18 cohorts that this PBL was implemented, training more than 800 students, it involved almost 50 persons as teachers (36), tutors (18) and research assistants (8). During the first fifteen cohorts, teachers also performed the tutor role. Almost all of the persons involved are included in the coordination team, having a minimum of 12 members (six teachers, one for each course and six tutors). From year to year, the team members vary, just the IEM team (normally two teachers, responsible for the Introduction to IEM course and Integrated Project) was stable in the 18 cohorts.

This team diversification introduces an additional effort: to introduce the PBL learning methodology to the new members (normally they do not know this methodology or are not accustomed with that). In charge of this introduction is the coordinator that should explain all the process, phases, milestones, assessment model, among others technical aspects. Most important are the soft aspects: to make the new member feel comfortable with this methodology and working in a team. Some reactions were the scepticism at the beginning but after some cohorts they just recognize the value of it. It is interesting to report that in one of the last meetings of the current year, one teacher said: “I like working with this methodology, we are not alone!”

This collaboration is visible for the students that see this way of working as an example. In the current year, due to the COVID-19, the coordinator was not available in the first session with the students (the most important session) to present the PBL and the other IEM teacher had this role. Another visible aspect is when all teachers are present in the oral presentations of the students, giving feedback to teams and providing opportunities for the reflection on the next steps of the project. Another example of extreme importance is the extended tutorial that teachers participate together with the student teams. As sometimes the feedback of each teacher can be contradictory, the extended tutorial is an exclusive meeting of each student team with all the teachers, in order to listen to the doubts and difficulties that teams could have. Having all teachers in the same room with each student team allows students to hear, understand and discuss teacher feedback.

5 Final remarks

Team teaching in project-based learning experiences in engineering education is a specific form of team teaching in higher education. It shows a number of additional features that go beyond teaching and planning for teaching and learning with two or more teachers. The benefits and challenges of this specific form of team teaching are, therefore, also more elaborate. As can be seen in the first part of the literature review, teachers in PBL need to facilitate learning activities from the start till the end of a project and need to be aware of the learning processes of their students. This requires more communication and agreement within teaching teams than the more traditional forms of instruction. The interdisciplinary nature of projects and the different role that teachers in PBL teams have when supporting students also asks from teachers to be not only informed about the expertise their colleagues have, but also the specific planning of content delivery and the contribution of disciplinary areas to the final solutions proposed by the student teams needs to be in the centre of their joint attention. The practical experiences as described in the second literature review of a specific teaching team confirms this need for close collaboration and the initial resistance that team teaching can provoke. Being part of a teaching team in an intensive method like PBL requires a strong involvement of all team members and attention for the psychological, communication and organisational aspect that team teaching asks in PBL asks from all team members. This extra commitment though, is, according to findings from the literature and the experiences described by the authors' team, compensated by the rewarding learning experiences of both students as well as teachers.

Although the scope of the current study is limited due to the use of SCOPUS as the single database for the literature review, the narrow definition of team teaching in the keywords and the focus on a single team of practitioners for the second literature, this limited exploration already shows that the role of the teacher as a team member in PBL is crucial to make the learning experience successful for students. Further exploration of the literature on specific roles of teachers in team building, team organisation and management and team communication is needed to get a better insight on how to optimise teaching teams for working with student teams. An interesting idea for future work could be to carry out a structured survey on the students' perception regarding the collaborative work of their teachers.

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Online assessment: more student cheating than on-site?

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Abstract

This paper discusses online student assessment which is one of the major concerns of higher education institutions during these pandemic times, forcing teachers to teach and assess in different ways and conditions than when using regular methods. Online assessment brings more challenges for the teachers and the fear that students could cheat more than in on-site or face-to-face conditions. More than a surveillance task, it is a question of having justice among different students' socio-economic and learning conditions. Ethical issues, respect for the colleagues and trust in their own work and more suitable learning assessment methods could be strong reasons for the students not to cheat. For the teachers, this is a complex and controversial issue. Finding the best ways to prevent this from happening is not easy. This could demand a balance between less time and more complex online tests that require a lot of imagination and creativity. This paper gives some examples of face-to-face written tests and online tests, comparing grades of two cohorts of students (2019_20 and 2020_21) from three different courses. Those courses are lectured in the first and third year of Industrial Engineering and Management (IEM) Integrated Masters degree and the first year of the Masters in Engineering Project Management, at the University of Minho. Some practical tips and suggestions will be given to prepare online tests (e.g. diversity of assessment methods, type of questions included in the tests, tests could not be the only assessment method ...).

Keywords: Engineering Education; online assessment; assessment methods; student cheating; academic dishonesty; COVID-19 pandemic.

1 Introduction

The radical change imposed by COVID-19 pandemic since 11th March 2020 (WHO, 2020) turned our world around totally. Nothing was kept equal to the way before that. Life at work, in the community, in school, they all changed. The computers and phones in our houses become our windows to the world and our means to reach Education. Students and teachers in the world become connected through the technology, discovering a completely new world of collaborative platforms and virtual learning environments. Nevertheless, it is necessary time to adapt and to adopt such technologies, fitting in it the traditional lectures and assessment methods that have been in use for centuries. On-site and face-to-face written tests become online digital tests and students are far away from teachers' "eyes". This creates doubts and the fear of students being able to cheat as they reach all the information that they need through internet or could order a service (Dawson & Sutherland-Smith, 2018; Silva, 2021).

Student academic dishonesty can take many forms, according to different authors: cheating on tests and assignments, falsification of data, plagiarism, inappropriate use of resources, taking credit for the work done by others and manipulation of academic staff (Park, 2003). According to Thomas and De Bruin (2012), in some cases, student academic dishonesty is not addressed by educational institutions for many reasons like psychological discomfort and also high workload and time needed to plan assignments focused to minimize cheating. Despite these issues, it is important to study the factors that lead students to cheat, since it may negatively interfere with the work of the learning environment as well as the process of student learning. For this reason, many teachers' concern is to find ways to prevent this, as has been reported, reason why there are a lot of options to prevent students from cheating (Dawson, 2021). Instead of focusing on ways to prevent it, maybe teachers need to learn how to use alternative assessment methods and understand the purpose of assessment methods according to the intended learning outcomes of the course and develop more effective student assessment.

Assessment can be defined as a feedback message about how students should fit into the learning (Uebe-Mansur & Alves, 2018). According to Earl and Katz (2006), the purpose of assessment practices can be viewed from three different perspectives: assessment *of* learning, assessment *for* learning, and assessment *as* learning. The first is, mostly, related to summative assessment and the latter two on formative assessment practices.

Attending to this context, this paper aims to analyze student assessment in the context of three different courses at the University of Minho, undertaken in 2019_20 and 2020_21. Also, it is intended to compare the classifications achieved by students in tests which occurred before COVID-19 pandemic (on-site assessment in 2019_20) and during the COVID-19 lockdown (online/hybrid assessment in 2020_21), discussing its implications for teachers and students, including academic dishonesty, in the form of cheating.

This paper is structured in five sections. This introduction presents the aim of the study and its theoretical background. Section two describes the context of the study. Section three presents the comparison of test grades in the three courses. Some suggestions for online assessment are presented and discussed on section four. The last section of the paper presents the conclusions and final remarks.

2 Study context

This section gives an overview of the two cohorts 2019_20 and 2020_21 of the three courses analyzed and compared in this study. Two of the courses are from Industrial Engineering and Management (IEM) Integrated Masters: first and third year (IEM11 and IEM31); and the third course is from the Engineering Project Management Master (EPM). The IEM of University of Minho is an Integrated Masters degree program of five years, 10 semesters. Each semester has 5-6 courses with five European Credit Transfer System (ECTS) each in a total of 30 by semester. At the end of the program, students obtain 300 ECTS. EPM is a second-cycle master with two years in a total of 120 ECTS.

2.1 TIEM & PSOI courses of the Industrial Engineering and Management program

The IEM first year course is called "Topics of Industrial Engineering and Management" (TIEM), which is the first curricular unit related with IEM program. Mainly, TIEM is an introduction to the design of production systems involving introductory contents such as teams formation, project management, IEM history and work organization models (e.g. principles of Scientific Management, Toyota principles as Lean Production roots, socio-technical systems and main industrial psychologists such as Elton Mayo, Herzberg, Maslow, Schein among others), design of production systems principles and tools, layouts, production dynamics and performance measures, sustainability and eco-efficiency measures and Lego Mindstorms for production systems prototypes. It is important to highlight that TIEM is integrated in a PBL learning environment as all Engineering and Sciences courses of the first year and first semester of a course called Integrated Project of Industrial Engineering and Management (IPIEM) (Alves et al., 2019). Normally, this course is lectured by three teachers, each one lecturing different modules of the TIEM contents.

The IEM third year course is Production System Organization I (PSOI) that is lectured in the first semester. It deepens the contents given in the TIEM, mainly explores Lean Production, Lean Thinking principles and methodologies to design production systems in the context of reducing wastes. Then, it is lectured a methodology to design or reconfigure production systems focusing contents such as production families formation following Group Technology and clustering methods, balancing methods and operation modes, standard work, layout methods among others (Alves et al., 2015; Alves, 2018; Alves, 2007).

Table 1 presents the number of students, number of teams and assessment elements in 2019_20 and 2020_21 cohorts.

Table 1. Cohorts' characterization of IEM's TIEM and PSOI.

Course	Cohort	Number of students	Number of teams	Assessment elements
TIEM	2019_20 on-site	84	13	3 team tasks (50%) + **2 on-site tests (60 min. & 75 min.)** (50%)
	2020_21 Hybrid	76	10	4 team tasks (55%) + **1 online test & 1 on-site test (40 min. & 75 min.)** (45%)
PSOI	2019_20 on-site	96	11	3 quizzes (5-minute) (15%) + 2 team tasks (10%+(40%+5%peer)) + **2 written tests (60 min. & 50 min.)** (30%)
	2020_21 Hybrid	98	11	3 quizzes (5-minute) (15%) + 2 team tasks (15%+45%) + **1 online test (30 min.)** (25%)

In TIEM cohort of 2019_20 the tests were exclusively on-site (in a traditional approach). For the cohort of 2020_21, the first test was already online and the second was on-site (a hybrid approach according to the teachers' choice due to the pandemic situation). The teacher who lectured the first module of the TIEM course had the will, since a long time, to have online tests and saw in the pandemic situation the opportunity to explore this way of assessment. During the semester, the university regulations related to tests (online/on-site) changed and the teacher who lectured the second module of the TIEM course returned to the on-site tests.

The on-site written tests could include true/false questions, select the right answer, direct questions for short answers, exercises, fill in the blank spaces, descriptions and interpretation of situations and cross arrows selection in a total of 25 questions. The online test was developed using Google Forms through the quiz functionality , had 20 questions of different types (short and long paragraph, drop-down, multiple choice grid, description of situations and interpretation, check-boxes, multiple choice, interpretation of images). These questions are divided by section according to the content and appearing to the students' section-to section. The students can always go back and correct anything. All team tasks are reviewed by the teachers and then delivered to the teams for improving for the IPIEM report and presentations. This course is totally aligned with the team projects developed in the context of PBL (Alves et al., 2017; Alves et al., 2019).

In the PSOI cohort of 2019_20, the tests were on-site (following a traditional approach). Due to pandemic reasons, the duration of the first semester of 2020_21 was shorter, so the PSOI lecture decided to have only one test. The on-site tests followed the same format of TIEM tests including different types of questions. Students' opinion was collected to know whether the test should be on-site or online. Most of the students preferred the test online. Even in 2019_20 (without COVID-19), all tests/quizzes were carried out online. Along with the PSOI tests, two tasks were assigned to the student teams. The first team task had less weight because it was considered easier. It consisted in giving the team an assignment aimed to search, analyze and interpret a published case study in an indexed journal that reports a design/redesign of a production system in a lean context (Alves, 2020). In the cohort of 2019_20, the second team task of PSOI had a weight of 45%, being 5% given by peer assessment. In the cohort 2020_21, this 5% weight was removed as the teams presented one at each time in the classroom, due to the pandemic situation. It is a hands-on activity developed in the context of two courses of the third year (Alves & Soares, 2020; Soares & Alves, 2019) but, attending to the restrictions of the room capacity, the teams were not all allowed to be in the room. Competencies developed by the students within these specific courses are explored and presented in the study of Alves and Soares (2020).

2.2 DPS course of the Engineering Project Management program

The course from EPM is an optional course called Design of Production Systems (DPS) lectured in the first year, of the first semester. The contents of this course are similar to the first part of the contents of PSOI but the second part is more basic as these students have a very heterogeneous background (i.e. some are not even from Engineering, but, for example, Journalism). At the same time, they are mostly all professionals working in companies. Table 2 presents the number of students, teams and the assessment elements.

Table 2. Characterization of the DPS cohorts.

Course	Cohort	Number of students	Number of teams	Assessment elements
DPS	2019_20 on-site	24	5	2 (5-minute) quizzes (10%) + 2 teams tasks (10%+(35%+5%peer)) + **1 written test (60 min.)** (40%)
	2020_21 Hybrid	30	6	2 (5-minute) quizzes (10%) + 2 teams tasks (10%+40%) + **1 online test (60 min.)** (40%)

As related to IEM's TIEM and PSOI, the DPS 2019_20 cohort tests were exclusively on-site and in 2020_21 were on-line as desired by the teacher.

3 Comparing tests grades results

This section is divided in two subsections, according to the results analyzed in the IEM and EPM courses.

3.1 IEM tests grades results

The graph of Figure 1 below is related to the analysis of grades achieved in the tests (0-100%) of IEM's Topics of Industrial Engineering and Management (TIEM) students.

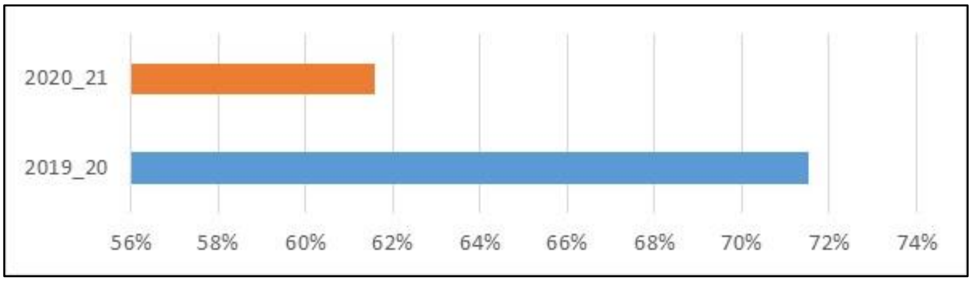

Figure 1. TIEM grades average of tests by cohort.

The same analysis from students' tests (Table 1) of IEM's Production System Organization I (PSOI) is presented in the Figure 2.

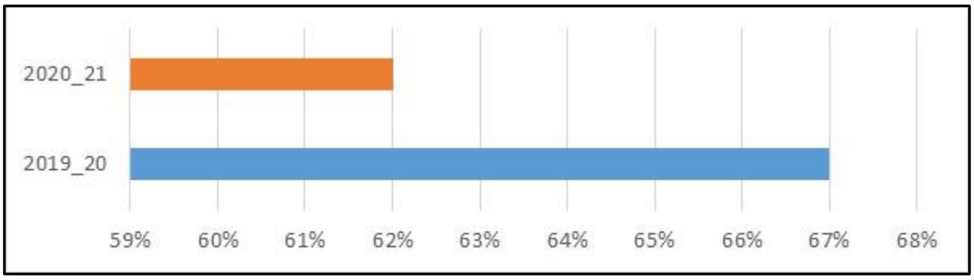

Figure 2. PSOI grades average of tests by cohort.

Based on these results, one of the first evidence that could be drawn is that the average of student classifications in the tests is lower in the online/hybrid assessment (2020_21) learning environments compared to the on-site assessment (2019_20). This is an interesting finding as one of the most common concerns about online assessment is that students will be able to cheat or employ other dishonest or unethical practices to achieve higher grades.

3.2 EPM tests grades results

The grades average of tests obtained for the course EPM's Design of Production Systems (DPS) were also analyzed, resulting in the Figure 3.

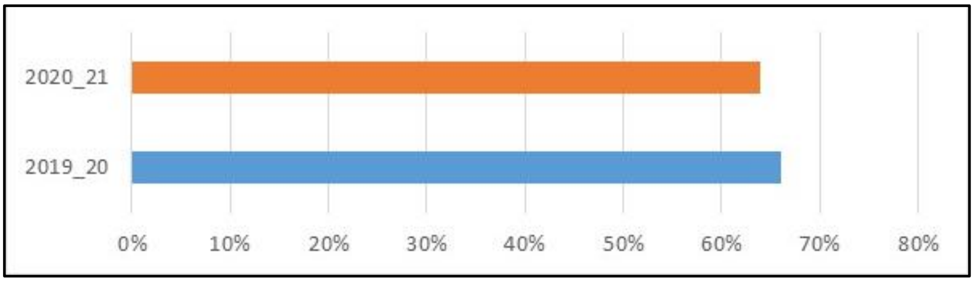

Figure 3. DPS grades average of tests by cohort.

In the same way, the two cohorts of students from the EPM course analyzed in 2019_20 and 2020_21 do not present hardly any differences in the grades average achieved by students in the tests. In this case, the formal assessment elements included in the course, in both years, were basically the same, which shows that, despite the fact that the students performed the test on-site or online, the learning outcomes of the course seem to be effectively achieved.

3.3 Discussion

There are a lot of variables that could influence the obtained test results (e.g. more difficulty, less time) but the teacher made an effort to balance those. For example, removing more practical exercises that are more difficult to do in a computer, like design a network or a Gantt diagram for a Project Management exercise in the case of TIEM course. Furthermore, the tests completed by the students during the semester and reported on Table 1 and Table 2, were summative assessments. Nevertheless, tests are not the only assessment component. Quizzes, held along the semester, and team tasks are some of the other components. Team tasks are mainly based on formative assessment, with a higher weight for this reason. For the PSOI, team tasks progress are monitored by using the Padlet tool (visual computer platform) (Alves & Soares, 2020; Soares & Alves, 2019). Figure 4 presents the Padlet, in this case, used by the teams of 2020_21. The Padlet is not part of student assessment.

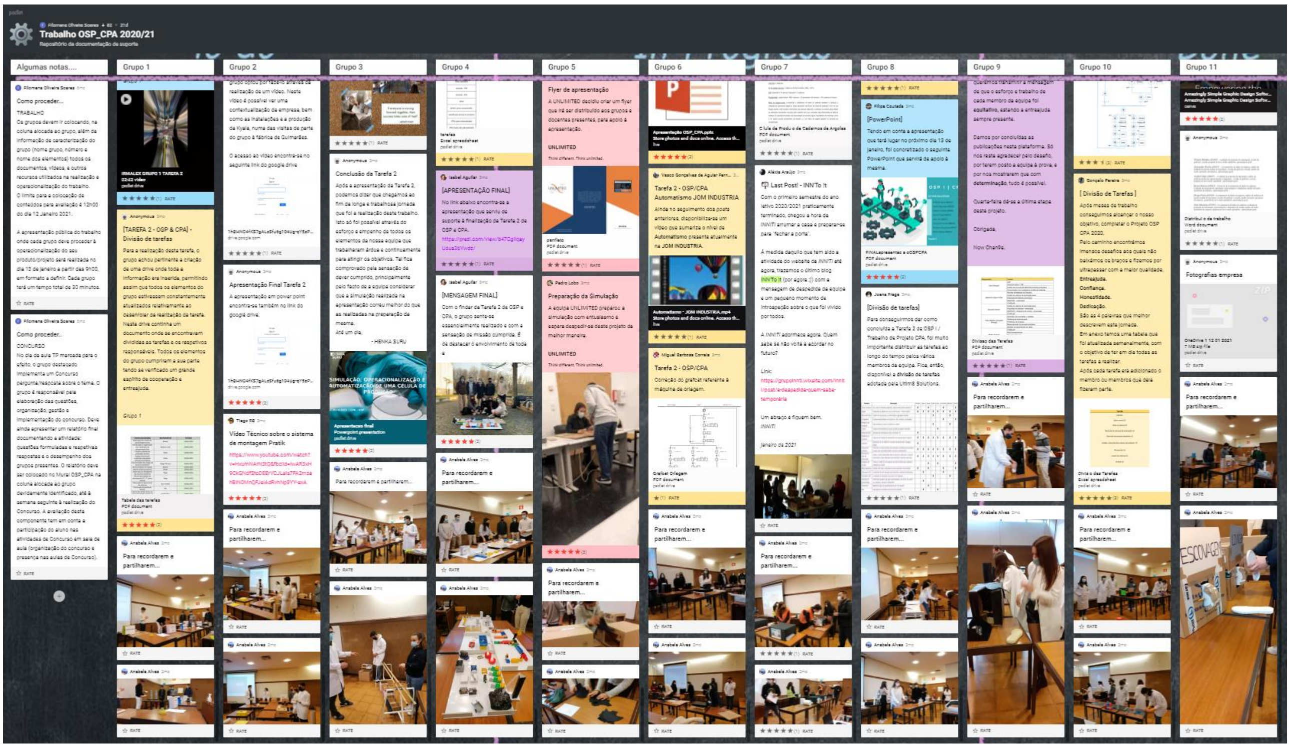

Figure 4. Teams work and progress shown through the Padlet (PSOI cohort 2020_2021).

In this pandemic time, it is even more critical that tests should not be the only assessment component because students are completely dependent of the technologies that they possess and many students do not have the desired conditions. Furthermore, house conditions (e.g. noise, one division, brothers that want to play or use the same computer, pets, among others) create constraints for student concentration and attention. This, as noticed by some students, could create unfair and unequal situations among the students.

The feedback of students obtained through the University Quality System (UQS) revealed some concerns related to the Google platform because of the limitation in reading the whole question (in a few cases). Students did not realize that this could be solved by pulling the scroll. A solution could be to use another tool or having shorter questions. Other concerns are common to the on-site tests, namely, the complaint about ambiguous questions. One student considered that the tests should be always on-site because of the stressful situation of on-line tests but this also could happen in on-site.

4 Suggestions for online assessments

Based on this study, a set of suggestions can be pointed out, for university teachers and educators, on how to prepare and deliver online assessments, taking in mind that assessment is also an opportunity for student learning, self-assessment and self-regulation (Earl & Katz, 2006). The first recommendation is the importance of using a diversity of assessment methods, which means that tests and examinations should not be the exclusive or single type of assessment method included in the formal assessment method of the curricular unit. Aligned with this assumption is the importance of using digital formative assessment tools, for monitoring student learning and providing feedback and interaction with students. Some examples of these tools may include self-test quiz and discussion forums (Google Forms, Kahoot, Quizziz, Miro, Padlet, Mentimeter, Slido, etc.).

Also, diagnostic assessment, before the start of the learning process, allows teachers to know where their students are at that moment. Formative assessments during the learning process allow teachers and students themselves to adjust the teaching and learning process according to that and to drive instruction practices centered on student growth, self-regulation and understanding (Barton, 2018; Maier et al., 2016). These approaches support the existence of a variety of learning styles, learning levels, recognizing differentiation in the classroom. It helps improve student growth by providing relevant and timely feedback.

Last, but not least a constant interaction from the teacher to the students is mandatory, as shown in PSOI cohort of 2019_20 (subsection 2.1). This allows students to be inquired about their assessment preferences, assuring confidence and commitment in the learning environment. This interaction could also take the form of promoting more moments for students to study small batches of contents by the short-duration and frequent quizzes, , adopting a one-piece flow strategy like in the production organization (Sekine, 1990), instead of having only one single test (production in batches).

Despite the advantages and the role of formative assessment for student learning, students are greatly concerned with summative assessment, usually focused in content-centered assessments, this is, the quantitative results achieved based on a classification scale. This type of assessment is mostly related to traditional forms of assessment, which are often highly content-driven and based on paper and pencil and, usually, focused on content-centered tests.

According to recent literature on online assessment in Higher Education in the time of COVID-19 (García-Peñalvo et al., 2020, 2021; Tuah & Naing, 2021), several recommendations for online assessment practices and measures should be considered. These recommendations include, for example, considering student diversity when selecting online assessment methods, assuring institutional and educator readiness for online assessment, using digital tools already available at higher education institutions, etc. In sum, we agree with Tuah and Naing (2021), who recognize that there is no cheat-proof online and paper-based examinations. In the rapidly shifting situation of COVID-19 pandemic and global uncertainties, educators in HEIs must explore the best approaches to reduce disruptions on students, teaching, learning and assessment (Tuah & Naing, 2021).

5 Final remarks

This paper analyzed three courses (TIEM, PSOI and DPS) of two master programs (EMI and EPM) of the Department of Production and Systems, School of Engineering of University of Minho that were offered in 2019_20 (before COVID-19) and 2020_21 (during pandemic situation) with slight differences. The paper discussed the average grades obtained in the summative component of the assessment (written and online tests). The teacher sought to maintain the same test conditions, introducing some slight differences due to the difficulty that students could have in doing online tests. The average grades in two of the courses was lower in 2020_21 than in 2019_20 and in the third course it was very similar. Of course, this could not mean that students did not cheat because a lot of variables influenced this process. Nevertheless, the average was not higher.

With this study, the authors recommend and alert that teachers need to diversify assessments components and approaches, and, in turbulent times, it is the opportunity to reflect upon the learning process. Students that like to learn and are self-regulated by nature continue learning, if they feel the assessment is fair. If not, they will feel disappointed and, even, demotivated. Otherwise, they could feel compelled to do what others do and be tempted to cheat. In this case, the problem is related to the student or to the method employed by the teacher? Is it an ethical problem or of motivation? And, for instance, when a student is integrated in a team (e.g. in a PBL project) is it a motivation or integration problem? Or a team problem? Is the grade important for PBL teamwork? A lot of questions remain without answer and could be interesting questions for deeper studies.

Limitations of this study are related to the reduced sample and the impossibility to isolate the variables that could influence the student grades, including that they are different students with different profiles and learning styles.

Acknowledgments

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Management of digital transformation of educational technology: key elements

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Abstract

The aim of this paper is to provide insight into the key elements of management of digital transformation of educational technology and to suggest avenues for future study. This paper offers an overview and classification of education technology and its links with the phenomena of digital organization and digital ecosystem, shows current digital trends in education technologies. Using technology to dramatically enhance universities' efficiency or scope is popular topic among academic society. But, the managerial issues of digital transformation of education technologies are still under question because most of the papers cover didactics and pedagogy issues of the digital education technology introduction. In this paper, we tried to summarize what are the keys to achieve digital transformation of education technology successfully. The findings suggest that digital transformation of education technologies need changes in content management and experience management strategies and practices, organizational and academic culture, decentralized model of operation, new financial and operative models, data-driven decisions and control tools. This results in necessity to manage digital transformation of education technology using tools of change and project management. Although the Digital Transformation has grown to include all sectors of education and business, there are some areas with more opportunities for future growth. This research was funded by RFBR, project number 20-010-00571 The Impact of Digital Transformation on Improving the Quality and Innovation of Services".

Keywords: Digital Transformation; Education Technology; e-learning.

1 Introduction

This study is intended to provide a more in-depth definition of digital transformation as key terms related to the development and use of electronic resources for a better electronic education system. Digital transformation is integrating digital technology into all areas of a business, fundamentally changing the way it is operated and providing customers with value. It is also a cultural shift that requires organizations to constantly challenge the status quo, experiment, and failure comfort. The digital transformation is the first in the company strategy's list of tasks, but in reality, several companies fail in their assessment of digital transformation levels, the Digital Maturity Test DES2018 results. Therefore, the goals are not being achieved and a lot of work remains to be done. The main keys to getting ahead and achieving a successful digital transformation in the field of electronic education will be explored in this paper.

That target customer is often students in education, though it could also be faculty, staff, alumni and others. For example, a digital transformation to transform the students' experience could include items such as: digitally recruiting students, using social media and text messaging as part of a data-driven decision-making process; Providing a variety of online learning options for students to choose from key points in their academic career; working with faculty and programs to convert courses into flipped and blended models; working in partnership with industry to provide digital badges and certificates to enhance career opportunities (Allan, 2010).

Combining these items into a wide-ranging digital transformation would bring together groups across the entire institution to put the student experience first. In addition, the institution could combine data from the new digital processes to determine its next transformation and power it.

All this can be the difference between a University of the 20th century and one of the 21st century. Over time, the most desirable students are expected to be attracted to those universities which embrace the digital age on their terms rather than being overwhelmed by them. This implies that being mindful of unused patterns in rising innovations and having the capacity to quickly tackle their potential to drive progressed results will be a key differentiator inside Higher Instruction.

1.1 The nature of educational technology

Educational technology can mean different things to different people. Those who practice as a technical career in this area have struggled to agree on exactly what the word would entail. Educational technology is a dynamic, interconnected process involving individuals, processes, concepts, tools and organization engaged in the analysis of problems and the identification, implementation, assessment and management of solutions to these problems in all areas of learning. Computers, television/radio, printed materials, and operating systems also represent a range of diversity in types of technology (Nel, Dreyer & Carstens, 2010).

For understanding the nature of educational technology, we need to know the development of the term. The earliest form of instructional technology was related to the use of audio-visual aids such as charts, models, maps, experiments, and concrete materials (AETC, 2008).

With the emergence of physical science and the subsequent technological revolution, an era of sophisticated hardware and software such as projectors, tape recorders, radio and television came into being, educational technology meant sophisticated devices and equipment used to display instructional content (AECT, 2007). Then came the age of the mass media, which for educational purposes contributed to the major communications revolution. There is a synergistic relationship between the domain as it is digitally represented by a wheel-like-virtual, with each domain on the periphery linked to a centre of theory and practice.

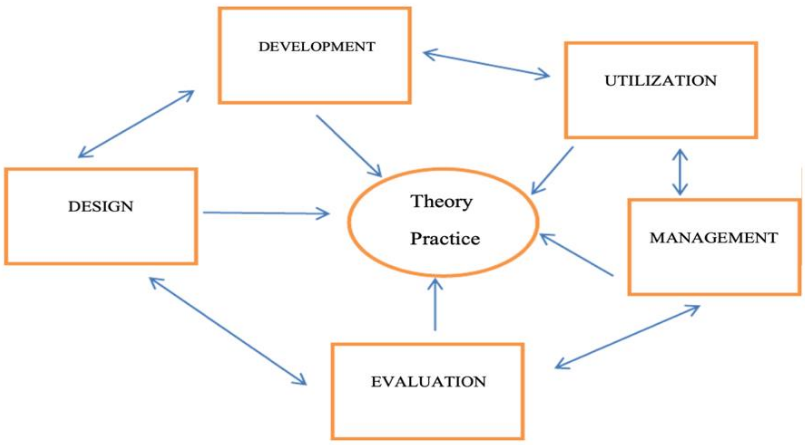

Figure 1. The Domains within the Field of Instructional Technology and the Relationship between Domains (Seels, & Richey, 1994).

This representation scheme was designed to avoid erroneous conclusion from readers that these domains are linearly related (Seels, & Richey, 1994).

The emphasis on systems approach gave rise to other aspects of education like: The educational planning or organization; The psychology of learning & The curriculum development and course design; The production of teaching-learning material; Audio-visual method of presentation and dissemination of information, storage and retrieval; The allocation and management of human and non-human resources; The cost effectiveness of medial in education; Innovation & Evaluations; partnerships in education (Vatolkina & Fedotkina, 2018).

Thus the nature of Educational Technology may be viewed from the entire teaching-learning processes like: Specification of goals and behavioral objectives; Analysis of the characteristics of the learner; Selection and organization of the content or subject matter to be learned; Methods and strategies of the presentation of the content; Use of aid-material, software and hardware, mass media and communication techniques; Effective arrangement of learning situations and learning environment; Effective classroom control and management, and; Continuous feedback and evaluation of the results. After defining educational technology, the main obstacles to implement such technologies start to appear.

1.2 Digital transformation trends in education

The digital transformation is not a new concept or process in education, as it has been already described in the section above, the transformation has been happening worldwide, and in some cases, it has been showing excellent progress and results (World Economic Forum, 2016). To evidence the purpose of this article, this section will list six trends, in what does digital transformation look like in practice (Agarwa, 2003, Aleksandrov et al, 2018).

1) Augmented Reality(AR) / Virtual Reality(VR) / Mixed Reality(MR)
2) Classroom Set of Devices
3) Redesigned Learning Spaces
4) Artificial Intelligence(AI)
5) Personalized Learning
6) Gamification

An observation at examples of digital innovations in education builds a closer relationship and empowers educators across the whole educational industry. In the classroom, educators in all grades begin to know the advantages of technology.

For distance learning, which integrates with the virtual learning environment the following components are crucial: content management system; on-line editor for the creation of materials for distance courses; training management system; virtual learning environment; other additional modules designed to provide a comprehensive solution for organizing distance learning at the university (Berman, & Bell, 2011). There is a large number of distance learning platforms, the most well-known of which are Blackboard, Moodle, eLearning Server 3000, Web Course Tools, ATutor, Claroline, Dokeos, LAMS, OLAT, Open ACS, Sakai, Acollab, Colloquia, COSE, DodeboLMS, ELEDGE (Cloete, 2000).

2 Methodology

2.1 Maturity level

This study namely the management of digital transformation of educational technology, with the purpose to identify key elements of digital transformation was developed in a qualitative way aiming to provide enough information to locate and help to manage different institutions in the process of adopting digital technologies as support for the new era of learning and teaching.

The study is based on the concept of maturity level created after a qualitative analysis of several universities strategies from European Union (including the United Kingdom), Russia, Australia and South-Asia. The key parameters observed in these universities strategies were the way they have been developed to assist institutions in their practice of delivering a quality technology enhanced learning experience for their students, teachers and staff.

The concept of maturity levels is currently quite popular and in its most general form characterizes the development of the ability of a system, process or technology to perform a certain activity and achieve certain goals in accordance with the established requirements or criteria for achieving success. Typically, successive levels of maturity reflect the progressive build-up of capacity and improvement in the performance of the activity or function performed. It allow to assess a set of heterogeneous qualitative and quantitative parameters of systems, processes or technologies, such as predictability, controllability, focus on stakeholders, completeness and effectiveness of the activities performed, and others. Maturity level models have been developed for a wide range of objects, including the organization's management system (ISO 9004), portfolio program and project management (P3M3), organizational processes (CMMI, ISO/IEC 15504), technology (ISO/IEC 15504) R 58048-2017), project management (OPM3, PMMM) (Rudenko & Subbotina, 2019).

Attempts to theoretically comprehend the logic of digital transformation have become a new stage in the development of models of maturity levels. So, at present, researchers have proposed general models of the level of maturity of digital transformation of an enterprise (an overview of the models is presented in (Aniruddha, 2020), production technology of industry 4.0 (MTMM (Gracel & Łebkowski, 2018), specific digital technologies such as artificial intelligence, data analysis, data management, and also for individual consumer properties of digital technologies (UMM is the level of maturity of the ease of use of a technology or service (Carvajal & Moreno, 2017). But there is still lack of comprehensive maturity level of digital implementation in higher education that can be used as a reference model for the digital transformation in higher education.

To build such model we decided to use the model that was proposed in ERASMUS+ CBHE project (# 586060-EPP-1-2017-1-RO-EPPKA2-CBHE-JP "Excellence in Engineering Education through Teacher Training and New Pedagogic Approaches in Russia and Tajikistan". (Smirnova, Lazarou, Vatolkina & Dascalu, 2019). This model is based on ISO 9004 logic and include nine key elements divided into five distinct levels for the success of digital transformation in higher institution. The adaptation comes with the goal to help institutions to locate their stage in implementing changes for adopting digital ways of teaching and learning, aiming to keep them in the market for the next decades, see table 1.

2.2 The use of the suggested model

The suggested maturity model was created for use at the enterprise level, or by the organizational areas in charge of providing leadership in technology enhanced learning and related services. The suggested maturity model was created for use at the enterprise level, or by the organizational areas in charge of providing leadership in technology enhanced learning and related services.

Performance Indicators are statements in a matrix that display the progress toward achieving best practices. The scale is a five-point rating system for self-evaluation and contrast. After a rating has been assigned, the reasoning for that rating on a scale of 1 to 5 should be given, as evidence to support the decision. The reasoning outlines key reasons for the ranking, which is then validated by proof. A URL leading to a planning document, paper, guidelines, service platform, or a written statement containing extracts or describing the source of the facts, or artefact, may be used as evidence. If necessary, this proof will be used to defend or support the ranking.

3 Results

To build maturity level for implementing a digital strategy at the university we explored approaches to digital transformation (Zaitseva, 2017), in higher education which include the following pillars: academic culture, customer focus, decentralization, measurement and control, clear objectives, conscious team, talent management, data and analysis. On the other hand we looked into the components of e-learning (MacDonald, 2005; Hammad, 2018; Usoro, 2008). “Diverse higher education institutions used information technologies as a key strategic to reducing costs and at the same time to support initiatives in advancing student centred flexible learning, and improving the quality of teaching” (Lip-Sam, 2015).

(Marshall & Mitchell, 2007) proposed a Benchmarking With The E- Learning Maturity Model, which provides an institution's understanding guide of their e-learning capability, and they list 13 categories which they believe to be essential to create a model for a better understanding of the obstacles that e-learning organizations face, as well as the resources that emerging technology and pedagogies provide for promoting student learning. As the result we proposed the following components of the maturity level for the development of digital strategy:

1) Development of a policy for the development of educational technologies
2) Deployment of educational technology policy
3) Exchange of knowledge, information, best practices in the field of application of educational technologies

4) Educational technology infrastructure
5) Monitoring the effectiveness of the application of educational technologies
6) Application of electronic educational technologies
7) Application of active educational technologies
8) Advanced training in the field of application of educational technologies
9) Postgraduate training

The digital transformation of education maturity model can be applied to all educational levels. Adapting existing models to match specific needs is wiser than proceeding without any plan. However, flexibility is needed to adapt a model to a given situation. Digital transformation at higher institutions can vary considerably in complexity and size. The maturity model described above is comprehensive – it covers all the options that can be included in a complex digital education development project. However, some of the elements can be simplified according to project's objectives and requirements, such as budget, expertise or organizational constraints. Future studies can complete the dynamic of this maturity model suggestion, adding an alternative strategy of how implement such technologies efficiently.

4 Conclusions

Companies have had to begin a transformation to adapt to the digital era. Digital transformation is reshaping the manner in which organizations emerge, operate, and develop (Chan & Chung, 2002). It also introduces changes in how to enter the market and deliver services. Higher Education institutions are no exception. Therefore, why university classrooms should undergo digital transformation? This question should be answered before the introduction of the main steps to a successful digital transformation in education. It is necessary to analyse the potential obstacles or roadblocks that an organization may face in order to understand how a complete and effective digital transformation will take place. By understanding those issues, they can be overcomed. Improved standards for the training specialists define the current state of education, which implies the relentless search for new approaches and resources to increase the efficiency of the educational process. Enhancing education and enhancing its efficiency is assured by the use of the management of implementation of newest technologies. This research introduces a maturity model that that portrays digital transformation as a dynamic ecosystem of capabilities. The model proposed answer the questions, from where to start and where to go, proving useful in each phase of transformation assisting in identifying gaps, determining key areas to focus on.

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Table 1. Maturity level for the development of digital strategy at universities.

Key Elements	Maturity level				
	Level 1	Level 2	Level 3	Level 4	Level 5
1) Development of a policy for the development of educational technologies	The planning process is not systematic. Policy and goals are undefined.	There are elements of a policy-making process for educational technology development. The goals in the field of development of educational technologies are included in the general development policy of the university.	The policy-making process has been further developed to include an analysis of the needs and expectations of students and teachers. The planning process involves examining changing external trends.	A structured process for setting policy and goals is in place. The policy in the field of development of educational technologies exists as an independent document. Trends and resource availability are assessed and examined before plans are approved.	The educational technology policy is defined, regularly reviewed, and it can be demonstrated that the policy has led to the achievement of education quality objectives. Effective monitoring and reporting mechanisms are in place, including the use of stakeholder information in planning.
2) Deployment of educational technology policy	Performance indicators related to the application and development of educational technologies have not been determined.	Policies are converted into indicators for faculty assessments. The performance of the indicators is not assessed systematically.	The policy is converted into indicators for the assessment of faculties, departments. The progress of work to achieve the indicators is assessed. Positive and negative deviations from the plan are analyzed and appropriate action taken.	The policy is converted into indicators for evaluating faculties, departments and teachers. The assessment of indicators is associated with the system of labor motivation and affects the bonuses for departments / teachers. The progress of work to achieve the indicators is assessed. Appropriate action is taken.	The indicators related to the application and development of educational technologies are regularly analyzed and updated in accordance with the policy. An assessment of progress towards achieving the goals indicates numerous positive trends. Policy changes are communicated to relevant stakeholders and to all levels of the organization.
3) Exchange of knowledge, information, best practices in the field of application of educational technologies	There is no process of exchange of knowledge and best practices at the university.	There is an irregular exchange practices within individual departments (faculties, departments) in the form of methodological seminars and other events.	There is a regular process of exchange between departments in the form of methodological conferences, seminars and other events. There are elements of a best practice databank.	The exchange practices are carried out not only within the educational organization, but also with partners of the university and other interested parties. The information received from partners is disseminated within the university.	Management are used to develop educational technologies at the university and this has led to the achievement of the organization's goals in improving the quality of education
4) Educational technology infrastructure	A basic infrastructure has been created for the application of modern educational technologies. Not all teachers have access to infrastructure.	Planning and management of educational technology infrastructure is carried out. Legal and regulatory requirements are taken into account. Access to infrastructure is limited.	Periodic analysis of infrastructure and related processes is carried out with a focus on the future. Most teachers have access to infrastructure.	Evaluation of the effectiveness of the use of infrastructure in the educational process for planning in future periods. All teachers have access to infrastructure. The infrastructure meets the needs of the educational process.	Infrastructure is managed and developed with policy and educational technology development goals in mind. All teachers use such infrastructure actively in the educational process. Infrastructure efficiency increases and compares favorably with other organizations.

5) Monitoring the effectiveness of the application of educational technologies	Monitoring is not carried out.	Monitoring is carried out on a case-by-case basis, and there are no corresponding processes.	Periodic analysis of infrastructure and related processes is carried out with a focus on the future. Most teachers have access to infrastructure. Changes in legal and regulatory requirements are systematically tracked.	The monitoring process is carried out regularly. Monitoring is focused on the needs and expectations of teachers and students. Tracking procedures for legal and regulatory requirements are effective and efficient.	The monitoring process is systematic and planned. The collection of information from employees of the organization and students is carried out through professionally conducted surveys and through the use of other mechanisms such as groups for thematic sky poll.
6) Application of electronic educational technologies	Electronic educational technologies in the educational process are used unsystematically by individual teachers.	The university has created a subdivision of electronic (distance) education. There are distance learning programs.	The university has created elements of a digital educational environment. There are additional and basic educational programs implemented in a distance form.	The university has created a digital educational environment. Electronic courses have been introduced into some full-time / part-time educational programs of higher education. There are elements of a local regulatory framework.	The digital educational environment functions effectively at the university. Electronic educational technologies are widely used at all levels of education. A corresponding local regulatory framework has been created. MOOCs are created.
7) Application of active educational technologies	Active educational technologies in the educational process are applied unsystematically by individual teachers.	Active educational technologies in the educational process are used regularly within the framework of individual educational programs.	Active educational technologies in the educational process are used regularly throughout the university.	There are elements of a local regulatory framework. The educational technologies used are adequate and correspond to the goals and content of educational materials.	The university effectively uses active educational technologies at all levels of education. A corresponding local regulatory framework has been created. The effectiveness of the technology is regularly evaluated and improved.
8) Advanced training in the field of application of educational technologies	Professional development is not carried out systematically. Competence testing in the field of educational technology is not carried out.	Continuing education in educational technology is part of an overall development plan that is linked to university policies.	A system of advanced training in the field of educational technologies has been developed. At least half of the teaching staff are covered by this system.	An effective system of advanced training has been developed. Most of the teaching staff are covered by this system. There is a program for assessing the competence of teachers.	The effectiveness of the professional development system is assessed by regulation in order to improve the system. Most of the teaching staff are covered by this system.
9) Postgraduate training	Preparation of graduate students for the use of educational technologies in future teaching activities is not carried out.	Within the framework of postgraduate programs, a course in Pedagogy and Psychology is conducted.	A course in Pedagogy and Psychology is conducted, as well as other courses that allow to study the main modern educational technologies.	Beyond a course in Pedagogy and Psychology, other courses that allow to study modern educational technologies to a specific subject area are conducted.	Beyond a course in Pedagogy and Psychology, and other courses about modern educational technologies to a specific subject area, regular pedagogical practice of graduate students is organized.

E-Learning Development Strategy of the University: Comparative Study

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Abstract

The development of e-learning as an object of management in higher education institutions, as a rule, corresponds to a simple model of transition from the stage of initiative implementation at the level of individual teachers, departments or divisions to the stage of centralized strategic management of the implementation of e-learning tools, processes and methods at the institutional level. Although the development and application of e-learning technologies in the educational process is still an individual innovation, today it is part of the national policy for the development of higher education and affects the assessment of the effectiveness and competitiveness of universities. It means that institutional e-learning development strategy bridges the individual innovation activity of teachers and national priorities in quality and accessibility of higher education. Therefore, the objective of the research is to summarize, compare and study the e-learning development strategies of the higher educational institutions from EU, Russia, Australia and South-Asia to distinguish major types of the strategies, as well as tools and mechanisms embedded to achieve strategic goals. As a result of the comparative analysis of 20 e-learning development strategies of universities authors offer recommendations for the strategy structure depending on the functional and evolutional type of the strategy that were identified in the paper. This research was funded by RFBR, project number 20-010-00571 The Impact of Digital Transformation on Improving the Quality and Innovation of Services".

Keywords: e-learning, development strategy, university management.

1 Introduction

E-learning can best be described as the science of learning without the use of instructional material printed on paper but with the use of networked information and communication technology. E-learning is emerging as the paradigm of modern education with the progress of the development of information and communication technology. The great benefits of e-learning include liberating interactions between learners and teachers, through the asynchronous and synchronous learning network model, from time and space constraints (Sun, Tsai, Finger, Chen & Yeh, 2008). To describe this mode of teaching and learning, a number of other terms are also used including online learning, virtual learning, distributed learning, networking, and web-based learning. Although the term E-learning involves much more than online learning, since the letter "e" in E-learning stands for the word "electronic" and it would include all educational activities carried out by people or groups working online or offline with the use of information and telecommunication technology (Naidu, 2006).

E-learning has emerged as a promising solution to lifelong learning and on-the-job workforce training over the past few years. For companies to ensure that employees and channel partners are equipped with the latest information and advanced skills, and effective training methods are crucial (Akberdina, Kalinina & Vlasov, 2018; Aleksandrov et al., 2018). Rushing to fulfil this need, universities around the world are now offering thousands of online courses, including degree and certificate programs.

In 2001, MIT announced its commitment to making available, for non-commercial use, materials from virtually all of its courses freely on the Web (Shea, 2002). An advantage of e-learning over Instructor-led training (ILT) is that it can be developed and delivered much more quickly and can be used by a large population spread all over the world at the same time. It gives new role to the university as the driver for economic growth and social well-being (Karpov, 2017).

The worldwide market of e-learning services hit $222 billion funding in 2020, according to EdTechXGlobal data. The average annual growth rate is estimated at 7-10% in the next three years and it means the market will rise to $282 billion of dollars (Edumarket.digital, 2021). It shows that e-learning can be a strong and cost-effective alternative to studying in the classroom. As an integral part of academic and technical education, e-learning will keep rising. Efforts can continue to explore how a more enticing and reliable online learning experience can be developed. One approach to do this is to incorporate effective pedagogical approaches, to increase interactivity and personalization of the method, and to involve learners more (Zhang, Zhao, Lina-Zhou & Nunamaker, 2004).

2 Strategic management of E-Learning

2.1 Development of E-learning as a system

E-learning have grown over the last decade to encompass multiple modes of education and transmission of learning through collaborative and individual efforts (Tabor, 2007). In order to provide widespread collaborative participation and open access through the Internet and online networking, new technologies have been developed. In addition to new technologies, pedagogical approaches have been built to include various kinds of course models, giving learners both compensation and the ability to start learning synchronously and asynchronously (Dron & Anderson, 2014). A variety of competitive developments continue to be faced by the higher education industry, from higher levels of student competition to questions around higher tuition fees and, as a result, student debt.

While this is definitely a positive development to extend higher education to meet a larger and more diverse community of people, it is also a significant barrier for universities, which have to achieve better results with less funding. This is a regular occurrence, intensified by the COVID-19 pandemic, in developing countries such as Brazil. According to the Ministry of Education, 38 of Brazil's 69 state institutions have shut down completely in October 2020, with 21 teaching remotely and 12 remaining partially open. According to the government, approximately half of the more than 1.1 million students enrolled in federal institutions have had their studies halted. Conforming to surveys conducted by The Lemann Foundation and Datafolha in November 2020, the transition to online tuition has been impeded by the lack of computer and internet access among the country's poorest pupils. States were left to make their own options because there was no national plan to support the transition. Students' biggest concerns remain a lack of desire and difficulty sticking to a schedule, according to the survey results, which show that over 40% of students share devices to do their homework from home.

The emphasis on more strategic uses of e-learning is becoming relevant as the environment in which higher education institutions work evolves affecting their primary and secondary markets as well as their instructional and organizational structures. It is generally recognised that technology, demographics, government policy and economic strength are the main external factors of change (Fisser, 2001; Middlehurst, 2003; Wende & Ven, 2003). E-learning could be described as an open system of individuals (students and teachers) and non-human objects (systems of learning management and information systems) that are managed to maximize the results of e-learning and student satisfaction (Figure 1). As a purposeful system, the E-learning paradigm is synergistic. There is a dynamic interaction between the inspiration of students, the quality of course design, teaching roles, and the academic efforts of students.

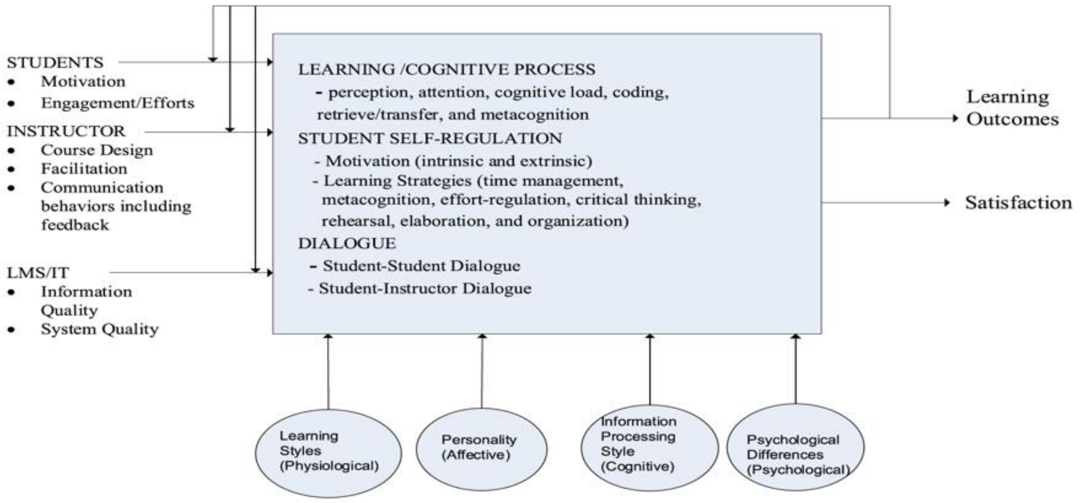

Figure 1. System view of e-learning, (Ashill & Nicholas, 2018).

The variety of existing models shows that the introduction of e-learning in higher education should be considered as a development project that can have a positive impact on building the capacity of the university and improving the effectiveness of its activities. The development and implementation of such a project is based on the tools of strategic management and change management, project management and organizational development. Strategic management is the ongoing planning, monitoring, analysis and assessment of all the criteria that an entity requires to accomplish its priorities and goals in long term period. E-learning development can be included as a part of educational, marketing or commercial strategy as well as strategy of internationalization or strategy of digital transformation. It could cover the whole university or be specific for the certain department or even discipline. In this study, the authors summarize and compare the e-learning development strategies of the higher educational institutions from Europe Union (EU), Russia, Australia and South-Asia. With this collected information, the findings show that e-learning development strategy process matches the traditional pattern shown in the Fig. 2.

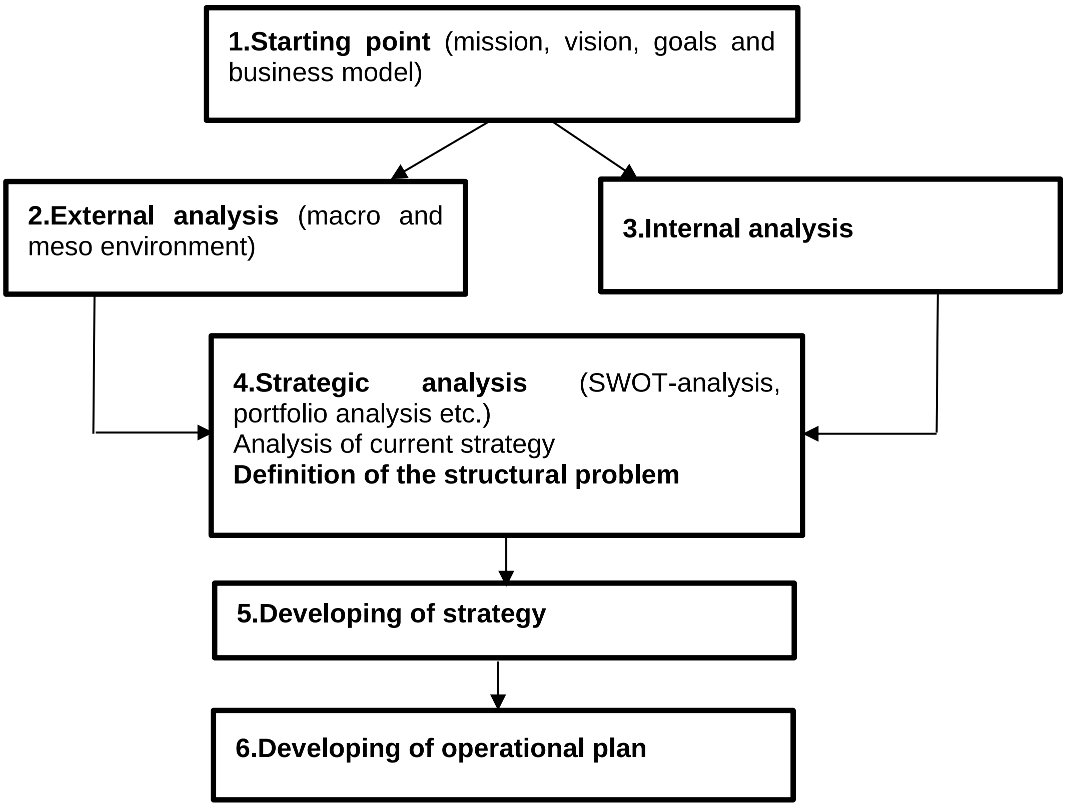

Figure 2. Strategic management plan.

The figure 2 helps to explain where is the focus of this article, section 4 strategical analysis, when we try to analyse current e-learning development strategies of different universities. To start, we need brief evidence of the national policies for the development of e-learning in higher education as its affects the institutional policies and competitiveness of universities.

2.2 National policy in e-learning development

New technologies foster innovation, however, it is people who are the real source of creativity. The government's position in the strategy was to provide the infrastructure to allow imagination, innovation and cooperation to drive the country forward as an international pioneer in our emerging digital environment by generating high-value content for itself and exporting it to improve growth and global competitiveness in the areas of e-learning, e-health and online gaming. The Bologna Implementation Report shows that "For new technologies to be used in an effective, efficient and trustful way in teaching and learning in higher education, certain framework conditions need to be met(Vatolkina, Fedotkina, 2018)… Action required for the implementation of these changes needs long-term strategic planning, changes in the legal environment and financial resource allocation". According the report, 38 EHEA member states have implemented some kind of national strategies or policies on the use of new technologies in teaching and learning. For example, small-scale initiatives have been developed by the National Agencies in Norway (NOKUT) and Sweden (NAHE) on quality standards for e-learning, and recommendations have been drawn up in the UK (QAA) on the quality evaluation of distance learning. Nevertheless, e-learning quality is not included as a regular or integral part of national quality reviews in any country, nor is any emphasis placed on the standards and guidelines established by the European Association for Quality Assurance in Higher Education (ENQA) on the quality in e-learning. Other organisations, such as the National Association for Developmental Education (NADE, Norway), the Joint Information Systems Committee (JISC, UK), and the Higher Education Academy (HEA, UK) have focused on the methodological development of e-learning assessment (The Horizon report, 2008). In "Bologna Digital 2020. White Paper on Digitalisation in the European Higher Education Area" universities should accordingly change their strategies and administration process to adopt e-learning and go in line with relevant national policies European Commission, 2018; Rampelt, Orr & Knoth, 2019). It will require transformation in all components of education management system at the university (Lyapuntsova, 2020).

The Australasian Council on Free, Distance and E-Learning (ACODE), which has published detailed benchmarks to impact policy and practice at institutional, national and international levels, is another experience. The Council on Higher Education Accreditation (CHEA) has established standards in the United States for the accreditation and quality assurance of distance learning, and the Distance Education and Training Council (DETC) has defined, maintained and promoted education excellence in distance education. In Russian Federation specific goals for the development of e-learning is set in the Federal project "Young Professionals" for the years 2018-2024 including number of MOOC created by the universities and number of tertiary students who has experience in formal e-learning.

3 Methodology and Results

3.1 Methodology of the study

This article was developed aiming for summarizing and compare the e-learning development strategies of the higher educational institutions from European Union (including the United Kingdom), Russia, Australia and South-Asia to distinguish major types of the strategies, as well as tools and mechanisms embedded to achieve strategic goals. This work is based in qualitative analyses from 20 universities, therefore, six universities from the Great Britain (GB), one university from the Netherlands (NL), one university from Switzerland (CH), four universities from Australia (AU), two universities from New Zealand (NZ), four universities from Russian Federation (RU), one university from China (CN), one university from Singapore (SG).

The analysis is based on the strategies adopted by these universities focusing on the implementation and use of digital technologies for teaching and learning in the last decade. Content analysis was implemented as research method. Content analysis is a quantitative analysis of texts and text arrays with the aim of subsequent meaningful interpretation of the identified numerical patterns. The following stages of content analysis are distinguished: determination of units of analysis; calculation of frequency distributions; interpretation of the results obtained.

Categories and units of content analysis are highlighted in the context of the study objective: a) type of e-learning strategy; b) vision of university e-learning strategy; c) strategic strands and relevant goals of the e-learning development strategies. Such an analysis allows to obtain reliable results when comparing organizations belonging to the same type of economic activity.

Content analysis show that there are following two major types of e-learning strategies:

1. Specific Digital Education Strategy presented as independent document covering objectives and tools in the field of e-learning or broader digital education strategy or distance education strategy;

2. E-learning strategy as the part of the other strategy - overall Institutional Strategy or Digital Strategy or Digital Campus Strategy or Overall Education Strategy.

There are key drivers for universities to embrace digital learning and to achieve our objectives we will deliver the vision of the universities that understand which role e-learning plays in university development to engage locally or globally.

Table 2. The strategic visions in digital learning of the higher educational institutions from EU, Russia, Australia and South-Asia.

University		University's Vision on digital education strategy	Type of strategy
1	University of Oxford (GB)	The goal is to ensure that Oxford remains a premier institution for teaching, adopting the very best of teaching innovations that are made possible by digital technology.	Specific Digital Education Strategy
2	University College of London (GB)	To establish a digital learning infrastructure that connects students with each other, with staff, with research and with the wider world.	Digital Learning is the part of the Institutional Education Strategy
3	University of Surrey (GB)	The digital learning strategy provides a vision of how an institution can nurture and sustain a rich portfolio of digital learning opportunities.	Specific Digital Learning Strategy
4	University of Greenwich (GB)	The University aims to provide a secure, reliable and feature rich digital environment for learning, teaching, research and professional services now and in the future, as technologies and the educational environment evolve.	Development of e-learning is the part of overall Strategy
5	University of Leicester (GB)	Developing digital skills and capabilities are strategic priorities for the University of Leicester as it works towards the ambition of becoming a "discovery-led university" that is "ever more focused on innovation	Development of e-learning is the part of Specific Digital

			Campus Strategy
6	Ulster University (GB)	Empowering people through digital;	Development of e-learning is the part of Specific Digital Strategy
7	Tilburg University (NL)	Digital Education Enhancement Program (DEEP) is designed to achieve: 1 Enhanced learning: the digital enhancement of personal learning and development. 2 Enhanced collaboration: the creation of a modern, networked learning community.3 Enhanced support: digital educational logistics and support that nurture TiU-shaped professionals.	Development of e-learning is the part of the Institutional Strategy
8	University of Geneve (CH)	The Digital Strategy is a tangible expression of the University's global vision, presenting a series of objectives aiming to strengthen the institution's digital activities and projects, as well as helping to develop new initiatives, thereby contributing to the digital transformation that is underway in society and in the world of academia;	Development of e-learning is the part of Specific Digital Strategy
9	University of Wollongong (AU)	Our digitalisation priority will see us pursue projects and redesign processes to enhance our digital capacity and teaching, learning and research practices.	Development of e-learning is the part of the Institutional Strategy
10	University of South Australia (AU)	The University of South Australia will be recognised internationally for its use of innovative digital technologies to deliver a compelling and industry-relevant learning experience for students;	Specific Digital Learning Strategy
11	The University of Melbourne (AU)	Melbourne graduates will be sought after for their creativity, their rigorous and ethical approach, their social awareness about global challenges and their readiness for an increasingly digital and changing world;	Development of e-learning is the part of the Institutional Strategy
12	Griffith University (AU)	Griffith's strategy is to be at the leading edge of digital innovation to enhance the student experience and Griffith's reputation as a university of influence;	Development of e-learning is the part of Specific Digital Strategy
13	University of Auckland (NZ)	To become a customer-focused organisation, the University requires a customer experience design capability. This capability consists of a design-thinking practice guided by meaningful analytics and by continuously-updated customer-journey models, and facilitates co-design processes in which customers participate directly;	Development of e-learning is the part of Specific Digital Strategy
14	University of Otago (NZ)	The University will be known for its leadership and excellence in teaching, learning and support of distance students and its distance education programme will reflect the University's distinctive contribution to national and international education;	Development of e-learning is the part of Specific Distance Education Strategy
15	Higher School of Economics (RU)	The university's strategy in the field of online learning is aimed at creating models of the educational process using online courses and providing conditions	Specific Online Education Strategy

		(organizational, financial, technological, methodological, personnel) to increase the effectiveness of such models;	
16	The Southwest State University (SWSU) (RU)	Information and communication technologies are widely used in education. ICT technical means have formed new directions in education, such as e-learning, mobile learning, online learning, and distance learning. One of these areas - distance learning, appeared on the basis of distance learning and nowadays has become popular in general education;	Development of e-learning is the part of Specific Distance Education Strategy
17	St. Petersburg State Electrotechnical University (RU)	The strategy in the field of e-learning and distance learning technologies (is a formalized set of principles coordinated with the development priorities of the university, on the basis of which an action plan is formed to saturate the educational process with information and communication technologies;	Specific E-learning and Distance Education Strategy
18	The Chinese University of Hong Kong (CN)	Enhance critical thinking and self-learning skills, using eLearning and innovative pedagogies, to nurture students as lifelong learners and global leaders;	Development of e-learning is the part of Institutional Strategy
19	Singapore Management University (SG)	In the face of massive digital transformations, we can spearhead cutting edge ideas for business and public sector transformation, leveraging digital solutions, contributing to a better understanding of the impact of digital transformation on customer and citizen experience, and offering solutions for the management of such impact;	Vague e-learning strategy as part of Digital Transformation within Institutional Strategy
20	Ural State Law University (RU)	Ural State University of Law requires active implementation of e-learning tools and distance learning technologies at all levels of training, wide representation on online educational platforms, and participation in promising projects.	Development of e-learning is the part of Specific Digital Strategy

Table 1 identifies the analysed universities, shows the vision of each university on digital education strategy and also describes in which level its strategy is in its portfolio. The analysed strategies are available in full through their electronic addresses mentioned in the bibliographic reference of this article.

The proposed strategies stand on a pre-analysis of the where the university stands on the adoption of digital education technologies, due to its engagement being very much driven by the particular needs of individual departments and faculties or the enthusiasm of individuals. It took the view that institution-wide engagement is needed to bring about a more coordinated approach to new developments and a better understanding of the benefits of technology use.

It was understood that the institution own values are great guiding influence to implement the strategy successfully. As suggested by UCL's strategy "The Introductory Programme" is a tool to explore and to integrate interdisciplinary academic activities into the university, building an online student's community. The summary of the strategies analysed consist of three main strands to achieve the digital implementation triumphantly. Firstly, it stands on to achieve excellence in education through implementation of e-learning and digital technologies, fostering innovation and constantly looking for the new possibilities in implementation of digital technologies to improve quality and accessibility of higher education. Secondly, strategies seek to offer support for teaching and administrative staff. This aims to augment the use of innovative tools and spaces for collaborative learning, relevant training and resources. Online learning is the product of student participation, rooted in a rich immersive online learning environment, in a range of online activities. Online learning experiences of high quality give students a multitude of ways to collaborate and interact with content, learning materials, instructors and peers. They are diverse and fast-paced, and therefore, to a large degree, freeing students from time and location constraints. Thirdly, to provide proper digital infrastructure to connect students with staff, with other students, with research and with the outside world, promoting support network interdisciplinary education. All universities strategies studied in this article, agree on providing a high-quality technology blended environment for staff and students. This strategy step carries a physical infrastructure development needed to facilitate the use of systems and boost accessibility inside or outside its campus.

Based on the twenty universities' strategies above we analysed specific goals according to three strategic strands identified in the strategies. These goals are evaluated in the table 2.

Table 3. The three strategic strands and relevant goals of the e-learning development strategies.

	Strategic strand	The goals
1	Achieve excellence in education through the implementation of e-learning and digital technologies	To extend the areas of excellence in digital education that already exist and to ensure that all departments and faculties regularly review how digital methods might enhance their teaching and learning provision.
		To continue to support local innovations by providing incentives and mechanisms for their development, and increase activity to maximise their impact.
		To use appropriate digital technologies to develop more inclusive provision for different learning needs
		To improve the student digital experience, providing a high quality, technology-rich blended environment for student study.
		To develop the digital skills and capabilities of students and staff
		To enhance digital leadership skills
		To engage in digital activities across disciplines and in national and international digital communities of practice
2	Support students and staff in the implementation of e-learning and digital technologies	To support academic staff as innovative teachers by developing the functionality and usability of key digital platforms, world-class tools, support
		To support students by making collections of resources more accessible and relevant to their learning.
		To provide routinely available training on good practice in e-learning
		To change the role that we play within the University to become a trusted partner that empowers and supports our students and staff.
3	Development of digital infrastructure and relevant resources	To support the development of remote teaching by provision of a robust platform, standard templates
		To support the development of an enabling infrastructure for the use of students' own devices in teaching events, and future-proof it.
		To support the development of an enabling infrastructure for online assessment
		To clarify, and agree the resources needed to develop digital education
		To provide a distinctive digital infrastructure to connect students with each other, with staff, with research and with the outside world
		To forge strategic partnerships and leverage resources outside the University to accelerate our ability to deliver solutions

Table 2 demonstrates the finding of this research which are three strategic strands of the e-learning development strategies and suitable goals. The guiding principles behind the proposed strategies, such as supporting students and employees and introducing supporting infrastructure, were designed to ensure reliable and effective delivery for a university's core customers: academics, students, and professional services workers, with a focus on defining the possible digital state commodity and the future trends.

The implementation of strategies will require a number of economic, organizational, social and technological innovations at the universities including: curriculum design innovations, introduction of digital scholarships for staff, changes in staff motivation mechanisms, development in student-centered learning, introduction of digital micro-credentials, decentralized planning, improvements in feedback mechanisms(Akberdina, Kalinina, & Vlasov, 2018). Implementation of e-learning development strategies require innovations in strategic partnership management as an important resource of the content and technologies (Smirnova, Lazarou, Vatolkina & Dascalu, 2019).

The deployment strategy is the inspiration and attention of academic workers and it should be directed by students. In order to encourage and support departments and faculties, units work with the Enhanced Learning Technology team and establish their own priorities for the application of the use of new educational technologies. The Strategy sets out certain criteria for good practice for departments and faculties to be followed, such as defining local priorities with inclusivity in mind and recommending strategies to ensure continuity of online learning. It also encourages departments to consider the complexity of their practices, noting the number of digital technologies that can be applied across the university or elsewhere.

If the strategy is well implemented the following objectives can be delivered.

- Providing further chances for face-to-face encounters between teaching staff and students and between students and experts in the industry
- Supporting students to get involved with the industry
- Enhance the use of emerging technology to create genuine resources for experiential learning
- Provide versatile and tailored learning experiences to enable students through their degree to have more control of their success.
- Professionals with the requisite digital skills to succeed in their future careers
- Enable employees in improving digital literacy and the opportunity to assess and incorporate emerging digital technology into their teaching practices

4 Conclusion

Digital and Information Services are the future of education, therefore creating strategies to implement them successfully is the key to step ahead to the digital age and potentially improve learning, teaching and researching at any University. So much of what the University is seeking to achieve will be enabled digitally. This paper concludes with three strategic strands of high-impact to enhance e-learning effectively in universities, through the analysis of strategies of the higher educational institutions from EU, Russia, Australia and South-Asia. First, achieve excellence in education through the implementation of e-learning and digital technologies. The implementation of a framework for digital capabilities would enable universities to assess the needs of the customer, to set up training programs and to design experiences. Second, support students and staff in the implementation of e-learning and digital technologies. Providing sufficient professional instruction, through learning, supporting structures for students and academic workers, making the limits of space, time and distance no longer complex problems and the universe of questions open to dynamic discovery. Third, the development of digital infrastructure and relevant resources. To ensure and deliver an integrated, robust, agile and sustainable digital learning environment, investment in the framework of information systems is needed.

Furthermore, since e-learning is becoming worldwide, while innumerous universities are still struggling on the adaptation to this new era, this study provides strategies three strategic strands as ways to ensure that they can actively and effectively engage in e-learning.

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Bringing PBL to Education for Sustainable Development: University to Business (U2B) approach

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Abstract

Higher Education has to play a crucial and key driving part in providing Sustainable Development of society being a catalyst for it for the next generation. Its importance has significantly increased especially after adopting the 2030 Agenda for Sustainable Development by the United Nations; it is being recognized by increasing numbers of international community representatives. Higher Education plays a dual role in achieving all 17 Sustainable Development Goals. One aspect is integration of Sustainable Development issues in academic and research programs and projects. The other one is ability of Higher Education to promote them and empower their implementation in business and community. Higher Education has made a lot of progress in terms of embedding sustainable development at all levels in institutions, in sustainable development-based research, in curricula for sustainability, and boosting more collaboration between stakeholders in society. The aim of this paper is to share experience in applying Project-Based Learning in Sustainable Development curricula in Higher Education and identify the outcomes for different groups of stakeholders (teachers, students, businesses and society). This paper presents a case of National Research Mordovia State University in implementing University-to-Business approach (U2B) at the level of curricula that affect business community through engaging students in solving real problems in Sustainable Development. The study is based on content analysis of results of students' projects in Sustainable Development of enterprises and organizations, developing a maturity grid of organizational sustainability according to the Russian Federation Standard GOST R 54598.1 – 2015 "Management of sustainable development. Part 1. Guide". The results obtained show that providing good understanding of Sustainable Development for students Universities produce graduates that can take up leadership roles in taking decisions and translate the knowledge and skills to real-world applications.

Keywords: Higher Education; PBL; Sustainable development; University; Students; Business.

1 Introduction

Higher Education plays a dual role in achieving UN Sustainable Development Goals. On the one hand, it is reflected in integrating Sustainable Development issues in academic and research programs and projects. On the other hand, Higher Education promotes Sustainable Development philosophy and empowers its implementation in business and community boosting more collaboration between stakeholders in society.

One of the best ways to develop students' skills and solve real problems in Sustainable Development is Project-Based Learning. Project-Based Learning (PBL) is a widespread active learning strategy applied by Higher Education Institutions. According to assessment of the Active Learning Strategies Maturity levels Russian Universities are at the level of enlightenment in applying PBL – «while going through teaching and training learn more about the method benefits» (Mesquita et al, 2019).

The new Federal State Educational Standards of Higher Education in the Russian Federation that contain requirements for Bachelor's and Master's Degree programs include competences on development and implementation of projects. These universal competences are obligatory to students regardless of their majors within Bachelor's and Master's Degree programs. For instance, graduates of Bachelor's Degree programs should be «able to define tasks following the aims set and choose the optimal ways to solve them taking into account the law, resources and limitations» and graduates of Master's Degree programs should be «able to manage a project at all stages of its lifetime».

"Project-based learning is a student-centred instructional approach, in which learning is organized around projects. These projects involve complex, challenging and authentic tasks, on which students work relatively autonomously (with a teacher playing the role of a facilitator) and over extended periods of time. The students collaborate in various design, problem-solving, decision making and investigative activities, the final goal being a realistic product or presentation" (Popescu, 2012).

Although there are many different views on PBL a list of its common characteristics can be identified:

(1) Projects are central, not peripheral to the curriculum; students learn the main concepts of the curriculum via the project (Popescu, 2012).

(2) It implies a problem or a question to organise and steer activities and the activities results in a final project that address the question (Lima et al, 2012).

(3) It also entails involvement of student groups, or teams (Powell and Weenk, 2003).

(4) PBL requires taking into account limitations of resources; particularly time (Yevstratova et al, 2018).

(5) It is distinguished mostly by its interdisciplinary as projects are based on an open-ended problem and therefore they are not limited to one specific disciplinary area (Lima et al, 2012).

(6) It does not only involve students in their own learning, as any other active methodology, it also involves teachers on improving their own practices (Alves et al, 2016).

And besides, PBL allows to implement a University-to-Business approach (U2B) at the level of curricula that affect business community through engaging students in solving real problems in Sustainable Development.

Universities play a pivotal role in providing high-level skills, a world-class research base and a culture of inquiry and innovation. The landscape of University-Business collaboration consists of a large number of highly diverse domains – for example, research projects, technology transfer, enterprise education, entrepreneurial support for staff and students, etc. (Wilson, 2012)

Findings of the project 'The State of University-Business Cooperation in Europe' in which over 17K representatives from within HEIs and business were involved show that more than half respondents of both HEIs and business initiate their cooperation and almost all of them plan to maintain or increase their cooperation. Both groups of the survey participants mention mutual commitment, mutual trust, shared goals, and prior relationships among relationships that facilitate University-Business cooperation (Davey et al, 2018).

Existence and expansion of good practice is to implement the U2B approach in degree programme design and delivery. Learning through projects enhances graduates' skills levels and ensures a smooth transition between university and business environments increasing opportunities for students to gain relevant work experience during their studies.

Taking in consideration these important remarks the paper provides a case of National Research Mordovia State University in implementing the U2B approach at the level of curricula that influences business through initiating students' projects to solve real problems in Sustainable Development. Therefore, the purpose of the paper is to share experience in applying Project-Based Learning in Sustainable Development curricula in Higher Education and identify the outcomes for different groups of stakeholders (teachers, students, businesses and society).

2 Methodology and Application of PBL to Education for Sustainable Development

The study is based on the content analysis of students' projects results in Sustainable Development for enterprises and organizations in 2016-2021 academic years, developing a maturity grid of organizational sustainability according to the National Standard GOST R 54598.1 – 2015 "Management of sustainable development. Part 1. Guide". It should be noted that the projects is a part of the course "Sustainable Development Management" studied by students enrolled in two Master's Degree programs: "Entrepreneurship for Sustainable Development" and "Integrated Management Systems" at National Research Mordovia State University. PBL in the course is based on a multi-level approach aiming at moving students from global and national issues of Sustainable Development to organizational and individual levels. At the level of global issues the students study global initiatives in Sustainable Development, for instance UN Global Agenda 2030. At the national level, they investigate Sustainable Development strategies by countries focusing on strategic initiatives and national projects of the Russian Federation. At the organisational level students are supposed to study organization's sustainable development strategies, assessment of the maturity level of its sustainability, management solutions and best practices in promoting Sustainable Development values and achieving Sustainable Developments goals (SDGs). At the individual level students develop projects "My contribution to sustainable development: past, present, future" to specify the SDGs that they consider to be priority and the most important for development of mankind's future and make a critical reflection about their contribution to achieve each of 17 SDGs (Salimova et al, 2020). The projects developed differ by their nature depending on the projects' aims and tasks (Table 1).

Table 1. Projects by their nature in the Management of Sustainable Development course.

Projects	**by their nature**		
	Research	University2Business	Student2Community
National strategies for sustainable development	√		
Organization's sustainable development strategies	√		
Assessment of the maturity level of the organization's sustainable development		√	
My contribution to sustainable development: past, present, future			√

The study presents a case of developing a U2B project "Assessment of the maturity level of the organization's Sustainable Development" as an example of applying PBL in promoting Sustainable Development philosophy. The aim of the project is to determine the level of organizational maturity in relation to the implementation of Sustainable Development principles. Students develop the project in the context of the organization being studied as a case of their Master's thesis. It assumes close cooperation with an organisation / enterprise team and provides a dual effect: enhancing students' skills levels and increasing their opportunities to gain relevant work experience during their study and engaging the enterprise in solving Sustainable Development problems (Table 2). The main stages of the projects carried out throughout the course are presented in Table 2.

Table 2 – Project Stages and Activities.

Phase	**Classroom Activity**	**Activity in the Business setting**
1	Identifying and setting aims and tasks of the project. Teacher's instructions on the final report, competence evaluation, and project evaluation	None
2	Review on methodology of evaluation of organizational sustainability maturity level (GOST R 54598.1 – 2015 "Management of sustainable development. Part 1. Guide")	None
3	Project follow-up meetings	Business visits and meetings. Teambuilding at the organization / enterprise
4	Mentoring by a teacher (on request)	Developing maturity grid for evaluation of organizational sustainability maturity level (case of enterprise)
5	Mentoring by a teacher (on request)	Assessment of the maturity level of the organization's sustainable development by the project team
6	Mentoring by a teacher (on request)	Developing a profile of organizational sustainability
7	Final presentation of the project and delivery of solutions. Competence and project evaluation	

At the firsts two stages a teacher describes a project concept including setting its aims and tasks, methodology that can be applied, timeline, resources needed and results, explains how the competences acquired and the project developed will be assessed. These stages are carried out in classroom. The third and fourth stages are preliminary steps to the project implementation. Follow-up meetings in the third stage are assumed by the teacher to clarify the progress in planning students' projects. At the same stage students start active communications with an organisation / enterprise. Students deliver aims and tasks of the project at the organisation / enterprise that is a case for their Master' theses and build a team incorporating the staff of the enterprise. Further stages are implemented on the site of the enterprise but teacher's mentoring is not excluded. At the fourth stage, the project team develop a maturity grid to evaluate an organizational sustainability maturity level on the methodology of the GOST R 54598.1 – 2015 "Management of sustainable development. Part 1. Guide". Key project activities are carried out at the fifth and sixth stages that include specifically assessment of the Sustainable Development maturity level of the organization and development of the organizational sustainability profile by the project team. At the final stage, students present their projects and deliver their solutions for the enterprises.

3 Results

The project "Assessment of the maturity level of the organization's Sustainable Development" is integrated in the Management of Sustainable Development course in two Master's programs – Integrated Management System and Entrepreneurship for Sustainable Development at National Research Mordovia State University since 2016. In 2016-2021 academic years over 100 students' projects have been developed for different industries (Table 3).

Table 3. Projects by Industry / Sector.

Projects by Industry / Sector	**Years**						**Total**
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	
Agriculture, forestry and fishing	2	7	4		2	1	**16**
Manufacturing	4	4	8	12	4	5	**37**
Electricity, gas, steam and air conditioning supply		1	1	4	3	1	**10**
Water supply; sewerage, waste management and remediation activities				1			**1**
Construction		1	1	1			**3**
Wholesale and retail trade; repair of motor vehicles and motorcycles		1	1		1		**3**
Transportation and storage					1		**1**
Information and communication		1	1	1	3		**6**
Financial and insurance activities		2	2	1	1		**6**
Professional, scientific and technical activities	1		1	1	2		**5**
Education	1	2	1	2	2	1	**9**
Human health and social work activities	1	1	1				**3**
Total	**9**	**20**	**21**	**23**	**19**	**8**	**100**

Low number of students' projects in 2021 can be explained by incompleteness of project activities in one out of two Master programs (students are at the fifth stage of the project at the time of preparing the paper for submission). The highest number of the projects – 1/3 of them for six years are carried out for industries that are typical for the Mordovia region – Light engineering, Device engineering, Cable industry, etc. Almost 1/5 projects are developed for Agriculture and Forestry.

Methodology of the standard used implies applying a four-level scale to assess maturity of organizational sustainability from minimum to full maturity. Assessment criteria are practice of applying four principles of Sustainable Development: compliance with ethical standards, inclusion, responsible management, transparency. An excerpt of the students' project results is shown in Tables 4 and 5. The matrix for assessment of organizational sustainability maturity is developed by the same way for other three principles and practices respectively. The levels of maturity achieved by the company are marked in grey.

Table 4. Excerpt of matrix for assessment of organizational sustainability maturity (case of Forestry industry, Compliance with ethical standards principle).

Principles	**Practice**	**Stages of achieving sustainable development by the organization** →			
		Minimum maturity			**Full maturity**
Compliance with ethical standards	Traditions of sustainable development	Lack of knowledge and traditions in the sustainable development	Compliance with the main mandatory requirements of the Forest Code	The correlation of sustainable development with the benefits of business, its impact on society. Sustainable development is recognized as a critical element of professional practices, policies and procedures	Sustainable development is included at all levels of the organization, taking into account values and an ethical approach. Sustainable development is a part of strategic and operational planning and decision-making.
	Leadership	The leaders of the organization are not familiar with the principles and goals of sustainable development	Evidence of the organization's commitment to sustainable development, although it is not always consistent across all aspects of the organization (participation in the regional project "Forest conservation»)	Management's commitment to consistent sustainable development; published statements, policies, and sustainable development goals. Requirements of stakeholders in development and implementation of a sustainable development strategy are taken into account	Deployment of a sustainable development strategy in the organization. The organizational culture is based on the principles of SD. The organization implements them in its daily activities. Leaders by personal examples confirm their commitment to the principles and goals of sustainable development.

The materials presented in tables 4 and 5 and figure 1 are an excerpt of a student' project. Despite a general methodology used by students, each student project is unique since it is developed on the case of a single company taking into account management approaches and approaches to Sustainable Development used. Presentation of student projects' results allows to demonstrate a variety of approaches applied and compares the organisational maturity levels of Sustainable Development between organizations in the same industry.

Table 5. Assessment results of the maturity level of the organization's sustainable development by the project team (case of Forestry industry).

Principles of sustainable development	Practice of implementing SD principles	Average indicator by project team members	Average indicator of maturity level
Compliance with ethical standards	Traditions of sustainable development	1,75	1,88
	Leadership	2	
Inclusion	Identification of tasks and inclusion of stakeholders	1,75	1,75
Responsible management	Creating an atmosphere of trust and opportunities for sustainable development	2	2,25
	Key management tasks, e.g. supply chain	1,75	
	Assessment of environmental factors	3	
Transparency	Analysis	1,75	1,75
	Sustainable Development Reporting and transparency to stakeholders	1,75	
Overall maturity level		**1,9**	

Summarized assessment results of the maturity level of the organization's sustainable development are presented in a spider graph (Figure 1).

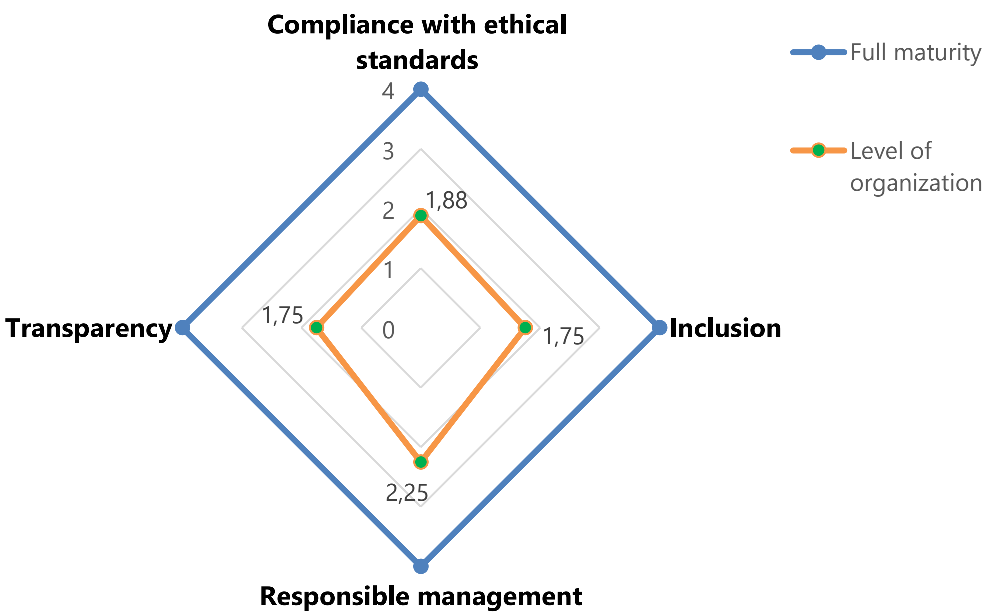

Figure 1. Spider graph of the maturity level for a Forestry Industry case.

4 Conclusion

The results demonstrate that, Project Based Learning in the Management of Sustainable Development course as a case of the Higher Educational Institution provides outcomes for different groups of stakeholders (students, teachers, university, and business community).

Master's Degree students can master their competencies required by the educational standards and enhance methods of conducting research based on the business cases. Their close interaction with an organization and a project team provides good understanding of Sustainable Development philosophy and their engagement in solving real problems in this field. It helps them to take up leadership roles in taking decisions and translate the knowledge and skills to real-world applications. One of the benefits of the approach is also the possibility of embedding the results obtained by students in their research and master's thesis.

It also changes the role of teaches and involves them in improving their own practices. On the one hand, they provide mentoring support to students with theory and methodology; on the other hand, they closely collaborate with industry and identify its needs and open-end problems that give ideas for further joint academic and research projects.

Universities can greatly benefit from expanding the U2B approach and increase the level of involvement of students and graduates in research, the attractiveness of PBL, deploy the Sustainable Development philosophy in the educational process. They produce graduates that promote Sustainable Development values and methodology in business community.

The University-to-Business approach based on applying PBL in curricula allows to develop the maturity profile of the organization's sustainable development, identify its strengths and areas for improvement, collect data for possible adjustments to strategic approaches and management practices in Sustainable Development.

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The Show Must Go On: Active Online Collaboration during COVID-19 – Mathematics Students Solving Real-World Problems

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Abstract

The outbreak of the COVID-19 pandemic caught the world off-guard, and the impact of the pandemic is unprecedented. Consequently, universities were closed, and lecturers were forced to adjust their teaching and learning practices and to shift their courses to online learning. This paper reports on Mathematics education students' active practices, experiences and reflections on their online collaboration regarding real-world problems. The aim was to determine how active group work could contribute to students' ability to solve such problems during the pandemic in an online environment. Although a mixed-method approach was employed, the emphasis in this paper is only on aspects of the qualitative phase. A cohort comprising 52 BEd students participated. They worked in 13 groups of four members each. Before students began with the assignments, they were introduced to active teaching–learning approaches, such as problem-based learning and cooperative learning. Group members were required to complete two assignments and submit them on the learning management system. Upon completion, randomly selected students completed task-based questions about their experiences of the assignments, mathematical skills and the type of thinking that they used. Students also had to reflect on the nature of their collaboration, personal interaction, and challenges they experienced. Students further assessed themselves as well as their peers regarding their active involvement and commitment. The data were manually coded and main themes emerged. The findings indicate that students initially experienced challenges with online learning. This learning mode forced them to take responsibility for their assignments, to assist each other in their learning processes, and to work closely as a group to ensure that they solved the problems correctly. The value was that students learned from one another, reflected on their efforts, and developed essential skills. The students enjoyed to work on real-world problems as they could identify with such problems. Social and teacher presence was crucial in the online learning environment. Some insights were gained regarding active online collaboration.

Keywords: Active Learning; Mathematics Students; Online Collaboration; Real-World Problem Solving.

1 Introduction

Albert Einstein said, "[e]ducation is not the learning of many facts but the training of the mind to think" (A-Z Quotes, n.d., n.p.). These famous words imply that learning is not about obtaining information as such, but rather about developing the ability to integrate and apply knowledge meaningfully.

The outbreak of the COVID-19 pandemic has adversely affected people across the world and the impact thereof is unprecedented (Del Rio & Malani, 2020). The pandemic forced people to think of new ways to survive and cope under different and challenging circumstances. As a result, universities were closed and it was compulsory for lecturers to adjust their teaching and learning practices and to shift their courses to online learning within a short time (Adedoyin & Soykan, 2020; Mishra, Gupta, & Shree, 2020). It was also expected of residential or contact students to return home and embark on an online journey in their respective courses. Consequently, students were forced to face an online environment – literally and figuratively – in order to pass. Such circumstances contribute to the challenge for students to be successful in their studies.

Succeeding in Mathematics is in itself a challenge for many students (Hasan, 2019). They often view Mathematics as a subject isolated from the real world with limited application in other contexts, such as Physical Science, Life Sciences and Geography (Li & Stylianides, 2018). Possible reasons for this may be traditional teaching approaches to which they had been exposed at school. These approaches often result in rote learning, the use of familiar algorithms, low-level thinking, and preparation for tests and examinations (Lubis, 2021). Students should, however, not only understand mathematical principles, but should also be able to apply them in new and unfamiliar settings (Li & Stylianides, 2018). Moreover, such activities may help students in developing persistence and confidence as they deal with "ambiguous problems and collaborate and engage in rigorous academic discussions with peers" (Kopcha et al., 2017, p. 32).

In pandemic circumstances, however, it is not necessarily trivial that students will actively collaborate online as they are acquainted with a face-to-face learning context (Jacobs & Ivone, 2020; Lubis, 2021; Scull, Phillips, Sharma, & Garnier, 2020). This paper reports on the online group collaboration of students in a BEd Intermediate Phase Mathematics module. The research was guided by the following research question: *how can active collaboration contribute to mathematics students' solving of real-world problems in an online environment?*

2 Context and Related Work

The following theoretical aspects are outlined briefly below: active learning, online collaboration, and solving real-world mathematics problems.

2.1 Active Learning

There is consensus that students should be actively involved in their learning and that traditional approaches, such as lectures, are no longer suitable for the development of essential knowledge and skills (Gravett, Yakovchuk, & Kinchin, 2020; Loh & Ang, 2020; Lubis, 2021). In addition, the World Economic Forum (WEF) (2016) highlights that active learning is essential for the future and the Fourth-Industrial Revolution (4IR) demands. Rands and Gansemer-Topf (2017) view active learning as a teaching–learning strategy where students are involved in performing tasks and sharing responsibilities such as active listening, peer questioning and discussing challenging problems in small groups. Active learning involves the facilitation of student collaboration as well as their engagement in problem-solving activities (Farrow & Wetzel, 2020). Through active engagement, students develop knowledge and skills that can enhance their higher-order thinking abilities (Jacobs & Ivone, 2020; Lubis, 2021). Bakar and Ismail (2020) elaborate that active learning encourages students to analyse problems and think logically. Kulikovskikh, Lipic, and Šmuc (2020) also refer to the role of reasoning and humans' ability in constructing new knowledge. Moreover, reflective thinking is essential. Veine et al. (2020) argue that reflection is a core activity to address complexity and unexpected outcomes, and provides an opportunity to learn from such experiences. Teaching–learning strategies, such as problem-based learning (PBL), project-based learning, cooperative learning (CL) and inquiry-based learning can be used to structure active student participation (Chen, Kolmos, & Du, 2020; Johnson & Johnson, 2019). In addition, learning management systems (LMSs) and platforms provide for students' engagement in the learning process and their development as self-directed learners (Han, Lim, & Jung, 2021). To summarise, active learning involves:

- *drivers for learning:* craft real-world problems or challenging scenarios and employ, for example, PBL, active collaboration and inquiry-based learning;
- *facilitators of learning:* lecturers plan for an active teaching–learning environment, provide adequate support and constructive feedback;
- *constructors of knowledge:* students actively construct new knowledge;
- *collaborators in learning:* each member contributes to group work, and enhances group dynamics; and
- *technologies for learning:* use a learning environment and technologies to provide for effective student collaboration.

2.2 Online Collaboration

The outbreak of COVID-19 compelled educators worldwide to use emergency remote teaching and learning (Adedoyin & Soykan, 2020; Mishra et al., 2020). The expectation was that online learning would replace face-to-face contact sessions to continue learning during the pandemic (Lubis, 2021). The aim was to have uninterrupted online teaching and learning under disrupted circumstances. Online learning platforms become the *modus operandi* for the delivery of subject matter, communication, and the application of assessment practices (Lubis, 2021). Han et al. (2021) highlight that effective facilitation through a learning management system is essential for online classrooms. Such an environment provides opportunities for students to engage actively in their learning, identify their own learning needs, manage learning responsibilities, reflect on their experiences, and develop as self-directed learners (Han et al., 2021). Collaboration offers students communication opportunities and the benefit of assisting each other, and adds a social component to their learning (Jacobs & Ivone, 2020; Loh & Ang, 2020). D'Alessio et al. (2019, p. 222) found that, when facilitators provide a "supportive community" in an online environment and facilitate students' collaboration and involvement, students benefit from such interaction. Already in 1995, Berge (p. 22–23) distinguished different types of interaction involved in online tutoring to succeed, namely *pedagogical* interaction (probe students for critical discussion), *social* interaction (promote learning, group members work cohesively and in a "mutual cause"), *managerial* interaction (management of learning), and *technical* interaction (software and technological aspects). Carrillo and Flores (2020) accentuate the importance of the following three presences in an online collaborative environment:

- firstly, *social* presence regarding students' ability to engage effectively, communicate purposefully, and develop interpersonal relationships in a collaborative environment;
- secondly, *teaching* presence, which involves the design, facilitation and guidance of cognitive and social processes to achieve meaningful outcomes; and
- thirdly, *cognitive* presence, which comprises the extent to which students construct meaning through communication and reflection in a community of practice (Carrillo & Flores, 2020).

Online collaboration, when administered effectively, ought to result in establishing the essential three presences, mentioned above (Carrillo & Flores, 2020).

2.3 Solving Real-World Mathematics Problems

Life is a journey to develop practical solutions to many problems. The exposure to real-world problem situations contributes to the development of skills and the preparation for future demands of work (Gravemeijer, Stephan, Julie, Lin, & Ohtani, 2017). Real-world problems must be meaningful, that is, they must match the student's abilities and must be relevant to the cognitive structure of the student (Lubis, 2021; Organisation for Economic Co-operation and Development [OECD], 2018). Mathematics is considered the language of technology and nature, and is a fundamental subject in many disciplines (Feuerstein & Roubik, 2019). The rationale for learning Mathematics is to enable people to solve problems that are sometimes complex, ill-structured and open-ended (Siagian, Saragih, & Sinaga, 2019). Consequently, students must possess a different set of knowledge, skills and perspectives from those of previous generations, to address the demands of the twentieth century. Such skills are communication, critical and creative thinking, decision-making, reflection, self-direction, collaboration and information literacy (OECD, 2018). Active problem solvers engage in three processes of mathematical reasoning typified by the following verbs: formulate, employ and interpret (OECD, 2018). Firstly, students must recognise the mathematical nature of a problem encountered in the real world and formulate it in mathematical terms. Changing a real-world situation into a well-defined mathematics problem necessitates mathematical reasoning (OECD, 2018). The problem must then be solved by using mathematics procedures, algorithms and concepts. Students also need to evaluate the solution by interpreting the results in terms of the initial situation. However, solving real-world mathematics problems online in COVID circumstances is a challenge for students. Mulenga and Marbán (2020) report on prospective teachers who engaged in online mathematics activities during COVID-19. Some students had positive attitudes towards working online, while others experienced some challenges, for example, they were unfamiliar with online platforms and technologies as well as long hours of connection and internet costs.

The next section reports on whether active group collaboration contributed to mathematics students' solving of real-world problems in an online environment.

3 Research Methodology

This research was initially planned for a face-to-face learning context, but was realised online due to the pandemic. Ethical clearance was obtained from the university and all ethical requirements were adhered to. A mixed-method research design was utilised. However, the emphasis in this paper is on aspects of the qualitative phase. In this research, an active learning approach was followed where participants were responsible for their collaboration and contribution to group work.

3.1 Participants

Participants involved a cohort comprising 52 BEd students enrolled for a second-year general Mathematics module with the aim of teaching future Grade 8 and 9 school learners. This module entails number patterns, algebraic reasoning and functional relationships, with the emphasis on an exploratory and active approach to solving real-world problems. At the beginning of the semester, the researcher randomly placed the students in 13 groups of four members each. Each group selected a group leader themselves and they had to give reasons for choosing the specific leader using a Google Form. The students remained in the same group for the duration of the semester and completed their assignments, while the group leader was responsible for submitting all the assignments online.

3.2 Online Activities

Group collaboration, assignments and data gathering and analysis are set out in this subsection.

3.2.1 Group Collaboration

Due to COVID-19, the module was presented online during the second semester, with all the activities on eFundi, the LMS of the university (refer to Table 1). As part of the preparation and to introduce students to essential skills, each student had to research PBL, active learning and cooperative learning, and submit an assignment based on these topics. However, in an online learning environment (Figure 1), it was a challenge to determine the extent to which students applied these active learning strategies. Group members had the freedom to decide on their own means of communication. They mainly used email, WhatsApp, Telegram, Facebook and Zoom, and used eFundi to upload their assignments. Since participants were residential students, online cooperation and the activities were challenging and unfamiliar to them, as they were used to working in groups in class. The researcher created one WhatsApp group for the whole class as a means of communication and support. In addition, every group leader created a WhatsApp group to enable direct and effective communication between the group members.

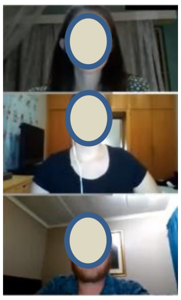

Figure 1. Students' active online collaboration and mathematical problem solving.

3.2.2 Group Assignments

Student activities involved two assignments during the semester (Table 1). Each assignment was uploaded on eFundi, and members had 14 days to complete the assignment as a group. Assignments required algebraic reasoning, problem solving and group decision-making. As part of group work, members had to solve problems where they shared responsibility, accountability, knowledge and skills. Students analysed the problems, gathered and organised relevant information, and presented their solutions together with proof of their argumentation and thinking processes. Each group leader then uploaded the solutions, and the researcher assessed their assignments using a rubric. The university online marking tool was used for assessment. Because of the pandemic, the researcher randomly selected 26 students (13 for each assignment) to individually complete task-based questions on a Google Form. Unfortunately, only 19 students completed these questions, probably because the semester ended and they lost interest. Students had to reflect on the nature of their collaboration in terms of the support from their group members, their responsibility, personal interaction and communication, the challenges that they experienced, and how they managed these. Furthermore, they had to allocate a mark out of 10 for themselves as well as for each of the group members. The online activities as shown in Table 1 below were involved, while Figure 2 gives an indication of all the activities that were followed.

Table 1. Rationale for selecting particular activities.

	Assignments	Rationale
1.	Individual assignment on PBL, CL & active learning	Introduce students to active teaching–learning strategies
2.	Group Assignment 1: Renovating bedroom	Apply formulas in real-life scenarios
3.	Individual task-based questions on Assignment 1	Students reflect on the assignment and collaboration
4.	Group Assignment 2: Cardboard box specification	Suggest the most economical size of the box
5.	Individual task-based questions on Assignment 2	Students reflect on the assignment and collaboration

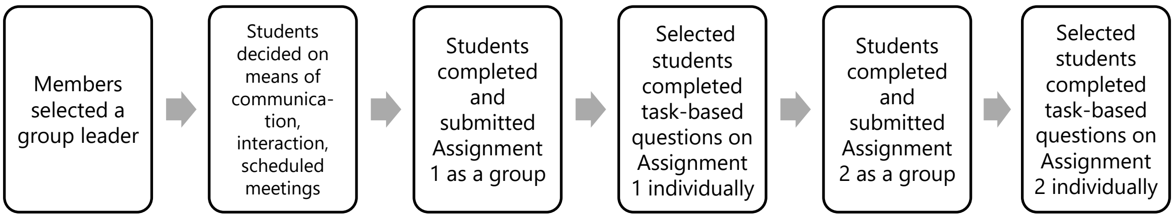

Figure 2. Diagram of sequential activities involved in this research.

Two assignments with real-world problems were included (Table 1). In the first assignment, students had to provide their parents with a total budget for renovating their bedroom. To do this, they had to determine the most cost-effective way to tile their bedroom floor with either ceramic porcelain tiles or wood angle click laminated flooring. They also had to find the cost of painting their bedroom walls. Students used the area of their bedroom and the area of the tiles to calculate the number of tiles (boxes) needed, as well as the cost of each type. Based on the cost, they indicated their preference. Similarly, they used the area of the bedroom walls to determine the amount of paint and the cost of it. Their budget had to include all expenses for the renovation of the room, such as labour, brushes, grout, glue and rollers. The lecturer selected this task because it was a real-world scenario to which students could relate. Students had to use reasoning skills and apply formulas and were required to do accurate and realistic planning of the budget.

The second assignment involved advising a cardboard box manufacturing company on the most economical size of a box. Students had to adhere to specific requirements provided by the company, such as the volume, a square base and a top and bottom of double thickness. In this task, students made 3-D sketches of their proposed box and its 2-D shape that can be folded into the 3-D figure. They wrote equations for the volume, height and cost of the proposed box. Students also selected a suitable graph from which they could determine the minimum cost of the box. As a result, group members were able to advise the company on the most economical dimensions of the box. The reason for selecting this task was that students had to plan a strategy to tackle the problem, apply formulas, do calculations, sketch and interpret a graph, and make recommendations based on their solutions.

3.2.3 Data gathering and analysis

Data were generated by means of two assignments and tasked-based questions (see Table 1). In each assignment, students had to show all their calculations accompanied by their reasoning processes. Members had ample time to interact with each other, plan together, solve the problems and submit their best solutions via the group leaders. Thereafter, a total of nineteen students completed task-based questions on the two completed assignments. There were eleven questions regarding their initial feelings when confronted with the problems, the problem-solving strategies, knowledge and skills they applied, their experience of the problems, and the possible changes they would make if they had to complete the problems again. Members also reflected on how group work assisted or prevented them from achieving success. Data were coded with the aim of answering the research question. Both concept-driven coding (based on literature and/or initial list of codes) and data-driven coding (which emerged from the data) were used, and themes emerged from the data.

4 Results and Discussion

The researcher analysed the data and obtained the following initial list of codes: mathematics, group work, plans, challenges, reflections, experiences and feelings. The codes were refined further and the following five themes emerged, namely problem-solving approach, group collaboration, technology, real-world problems, reflection and challenges. Table 2 displays some reflections of students' active involvement in solving real-world problems. Quotations are presented verbatim and unedited. Participant numbers are indicated in brackets, e.g. [P-number].

Table 2. Students' reflections on their active participation in the problem-solving activities.

Aspect	Exemplars from responses by students
Problem-solving approach	A problem was given that needed to be analysed before it can be solved. I used the problem-solving skills that I am familiar with [P-3] I was uncertain what to do. I had to read through the problem a few times [P-2] No, initially I did not know how to solve the problem [P-7] I created my own measurements and researched about renovating materials [P-4] I used pictures to represent the problem [P-1] I drew a diagram and wrote everything down that was expected of me [P-2] I used critical thinking to write down equations that I could solve [P-3]
Group collaboration	It helped a lot to get more than one opinion or point of view on the solution to the problem [P-5] The ideas of the other students help your own ideas to grow [P-17] We could build on each other's ideas [P-13] and the others think about aspects that I do not think of [P-16] I enjoyed to work together on the problems and to think about possible solutions and answers [P-6] Group work helped us because we could brainstorm together about the more challenging parts of the assignments [P-11] Group work helped me. There were three other people to ask for assistance when I struggled with something [P-1] I do not like group work, but I learned a lot from the others. Our team work made the 'dream work' [P-3] I learned a lot from my fellow students [P-14] One of our group members did not do his part [P-5]
Technology	Creating the ZOOM meetings was the most imperative part to share or communicate about the assignments [P-16]

	The WhatsApp group helped us to communicate with each other regarding our planning, progress and challenges [P-15] We struggled to communicate with each other [P-10] The others were not always available [P-13]
Real-world problems	I enjoyed the problems and they did not feel like work. It was challenging at times, but that made the problems exciting [P-10] They were very insightful. I realised that the presentation of Mathematics need not always be boring and monotonous [P-9] I really enjoyed the problems as they forced me to think outside the box [P-8] They were good because I could learn a lot from them. They are applicable to the real world and that makes Mathematics more realistic and understandable [P-12] They made me look differently at Mathematics. It is not a static subject, but even school learners should solve real-world problems and not only hear about them [P-3] I could see that Mathematics is not just about numbers, but also about real life. The problems can be solved easily, but requires critical thinking [P-11]
Reflection and challenges	It was helpful to reflect. We could realise our mistakes, try different methods until we agreed on the solution [P-4] It was an experience to work with people that you do not know [P-4] My group members made me think. I would have been unable to find some of the answers without their assistance [P-15] The problems were interesting and showed me a lot regarding my own limitations [P-8] I had the opportunity to grow and realise that I am a good leader [P-8] It was challenging to study online and to communicate with the others [P-3] The fact that we were not together, was a tough hurdle to overcome [P-18] and since we were not around the campus due to COVID-19, most of us were struggling with internet connection [P-5] We struggled to adhere to our planning in order to submit the assignments on time [P-10] and I sometimes did not have data [P-1]

The research question addressed in this section was: *how can active collaboration contribute to mathematics students' solving of real-world problems in an online environment?*

Students reflected positively on the contribution of online collaboration to their learning experiences, although they initially experienced some challenges in approaching a real-world problem (P-1, P-2, P-4, P-7) (see Table 2). Most members contributed to group work and enhanced their group dynamics. They used technologies, such as Zoom and WhatsApp, which enabled effective collaboration. Students were not only actively involved in their own learning (see Table 2), but also contributed to the learning of their peers. Members gained more than one point of view on the solution [P-5], they built on each other's mathematical ideas [P-13], and they thought deeply about aspects of real-world mathematics problems [P-16] and how to approach such problems. Furthermore, group members critically discussed and brainstormed the more challenging parts [P-11] and, as a result, they were forced to think outside the box [P-8]. For example, in the second assignment (card board box problem), many students thought that the graph should be a straight line, but it was a parabola. They could assist each other to solve this issue by selecting smaller values for the volume on the x-axis. In the process of achieving group goals, members assisted each other when they struggled [P-1], reflected on their problem-solving efforts, realised what their mistakes were, and used new ways to solve the mathematics problems [P-4]. Participant 15 explicitly stated, "[m]y group members made me think. I would have been unable to find some of the answers without their assistance." Regarding the value of addressing real-world mathematics problems, participants did not perceive mathematics to be monotonous [P-9] and expanded their views. They regarded such problems to be realistic, understandable [P-12] and insightful [P-9].

Active problem solvers also participate in mathematical reasoning, namely formulate, employ and interpret, as outlined by the OECD (2018). Examples are the following:

- students used mathematical reasoning to solve the problems (e.g. finding formulas for the volume and the cost of the box);
- they evaluated their solution by interpreting the results in terms of the initial situation (e.g. decided on the size of the most economical box based on their results and the given requirements); and
- students actively constructed new knowledge in solving these problems:
  - "I used critical thinking to write down equations that I could solve" [P-3]; and
  - "I drew a diagram and wrote everything down that was expected of me" [P-2].

These findings correspond with those by Farrow and Wetzel (2020) who state that active learning involves the facilitation of student collaboration as well as their participation in problem-solving activities. The online collaborative environment created a social presence in which students could participate effectively, communicate purposefully, and develop interpersonal relationships. A teaching presence, which involved the lecturer's design, facilitation and guidance of cognitive and social processes to achieve meaningful outcomes, was evident. Students could construct meaning through communication and reflection by means of their online collaboration. These findings correlate with the research by Carrillo and Flores (2020) who emphasise the importance of the above-mentioned three presences in an online collaborative environment (refer to section 2.2 above).

Some insights were gained regarding online learning. The teacher's presence assists students to feel secure in an active online environment. This provides adequate support and opportunities for constructive feedback. We suggest that real-world mathematics problems be related to students' experiences. Students were excited to solve real-world problems (e.g. renovate your bedroom), they were willing to take risks, and contributed to the success of the group. It was worthwhile for students to solve such problems as they could relate to the circumstances. However, a challenge in the online learning environment was the availability of data and the quality of the students' internet connection. These findings are in line with those of Mulenga and Marbán (2020) who indicated that prospective teachers experienced similar challenges when they engaged in online mathematics activities during the pandemic, for example some were unfamiliar with online platforms and often had no internet connection.

5 Conclusion

This research investigated the contribution of active online collaboration to mathematics students' solving of real-world problems during the COVID-19 pandemic. Results indicate that, although students experienced some challenges with the online learning environment, most benefited from their online collaboration. Students were actively involved in solving the problems and consequently developed new knowledge. They contributed to their own learning as well as to those of their peers. Students used to face-to-face environments had to adapt to student-centred teaching in an online environment where they had to become responsible for their own learning and for that of their team members. The contributions of the online collaboration were favourable despite the challenges that students experienced.

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Perception of Professors and Undergraduate Students of Engineering at the University of Brasilia (UnB) on Emergency Remote Learning Period in the context of the Covid-19 Pandemic

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Abstract

Due to the social isolation promoted in Brazil to reduce the number of coronavirus cases (Covid-19), local authorities of Brasilia suspended face-to-face activities. In-person courses of educational institutions were redesigned for the remote format. The main objective of this paper is to evaluate the perception of the Emergency Remote Learning Period (ERLP) from the perspective of undergraduate students and professors of the Civil and Environmental Engineering degrees of the Department of Civil and Environmental Engineering (ENC) of the University of Brasilia (UnB), through the application of questionnaires and data analysis. The secondary objectives are to identify the teaching methodologies and strategies, the platforms most used by professors, and the courses in the remote format with the highest student approval. A group of undergraduate students from Civil and Environmental Engineering degrees of UnB conducted this research in the course Project Management and Multidisciplinary Teams. The research was divided into four steps: technical literature review, data survey, data analysis, and discussion of results. In general, the students consider themselves adapted to the professors' methodologies. The evaluation criteria used are consistent, despite the overload of activities. It was necessary to redesign activities from the professors' perspective, which required effort since many professors had little or no experience with online classes. The most used methodology was direct instruction, also applied in the in-person format; the most used evaluation criteria were assignments, seminars, and class participation; the platform most used in the ERLP is Microsoft Teams, made available by the institution. The results contribute to a critical review of the emergency teaching model in the Covid-19 pandemic in Engineering Education and improve future applications.

Keywords: Emergency Remote Learning Period; Teaching Methodologies; Remote Learning.

1 Introduction

Due to the social isolation promoted in Brazil to reduce the number of coronavirus cases (Covid-19), local authorities of Brasilia suspended face-to-face activities in 2020 (Agência Brasília, 2020). Therefore, educational institutions had to adapt teaching methodologies to the virtual environment.

Remote Learning (RL) for higher education in Brazil stands as a challenge since it is linked to dubious learning quality and low student engagement (Finelli et al., 2018). Veiga et al. (1998) consider that educational institutions should continually rethink and improve their quality of services, evaluation systems, and flexibility, including RL. Many proposals for evaluating RL and ICT (Information and Communication Technologies) applied to RL were made by distinct researchers in the educational context. Key parameters are used to obtain the students' perception of remote classes, for example, access to the internet and the quality of this access, focus level during classes and post-classes studies, engagement in debates, and the adaptability to the methodologies used by the professors (Jesus & Borges, 2014; Silva et al., 2016; Cabanach et al., 2016; Finelli et al., 2018).

It is notorious that RL tends to be more exhausting. Thus, the use of innovative strategies and tools becomes an excellent way to improve learning. The great challenge in RL is constructing a dynamic network that promotes discussion and dissemination of knowledge (Veiga et al., 1998).

In the Emergency Remote Learning Period (ERLP) semester at the University of Brasilia (UnB), professors had to redesign the face-to-face courses for the remote format. As it is a remarkable fact in history, evaluations of the impacts of this transition on students' and professors' behaviors are essential to maintain the degrees' standards of engineering education (EE) practice. A group of undergraduate students from the Civil and Environmental Engineering degrees of UnB conducted this research in the course Project Management and Multidisciplinary Teams.

The main objective of this paper is to evaluate the perception of the ERLP of undergraduate students and professors of the Environmental and Civil Engineering degrees of the Department of Civil and Environmental Engineering (ENC) of the University of Brasilia (UnB) through the application of questionnaires and data analysis. The secondary objectives are to identify the teaching methodologies and strategies, the platforms most used by the professors, and the courses in the remote format with the highest student approval.

2 Method

The authors divided the research into four steps: technical literature review, data survey, data analysis, and discussion of results.

The consultation of the technical-scientific literature was conducted focusing on RL, active methodologies, and research related to assessing the quality of remote student learning. The platforms used in this step were: Google Scholar, Scielo, publications of the Brazilian Association of Remote Learning (ABED), and papers of scientific conferences. A summary of the review was presented in the Introduction section.

The platform used in the data survey was Google Forms. The questionnaires were directed to two audiences: the undergraduate students (number 1) and the professors (number 2) from the Civil and Environmental Engineering degrees of UnB. The authors defined the questions of both questionnaires according to previous studies from the review step. The main research questions were:

- What is the perception of student performance during ERLP by their perspective and by the professors'?
- Is there an overload of activities for students during ERLP?
- Do the students think that the evaluation criteria of the courses are consistent?
- Are the students adapted to the professors' methodologies during ERLP?
- What are the courses in the remote format with the highest student approval?
- How was the professors' transition from a face-to-face course to a remote environment? Did the course plan in terms of evaluation criteria and content change?
- Do the professors have previous experience in RL?
- Do the students and the professors believe in the possibility of hybrid courses in the future?

Then, the questionnaires were structured to understand the students' and professors' perspectives towards ERLP considering the research questions. The data analysis was conducted in Microsoft Excel, and the results compared to previous studies. Graphs and tables were used to explore the information gathered.

3 Results and Discussion

3.1 Students' Questionnaire

First, it is necessary to understand the current scenario at UnB in the context of the Emergency Remote Learning Period (ERLP) and Covid-19 pandemic. This teaching modality has numerous differences compared to Remote Learning because there is no extensive pedagogical planning. Most of the time occurs only the adaptation of the content to the online form. The result of a very rapid transition between the methodologies can highly affect students' absorbed content (Minha Biblioteca, 2020).

From the method detailed, 125 answers were obtained from undergraduate students of the Civil and Environmental Engineering degrees of UnB. The results are presented in Table 1 and Figure 1.

Table 1. Answers from Questionnaire 1: Students' Perception of Remote Learning Techniques.

Question	Answers	
(1) Is the number of activities proposed in the courses adequate?	Very Inadequate	7.2%
	Inadequate	40.8%
	Adequate	49.6%
	Very Adequate	2.4%
(2) Are the course assessments consistent with the content administered in the remote format classes?	Little Consistent	8.8%
	Consistent	69.6%
	Very Consistent	21.6%
(3) If you had the option to choose between face-to-face and the remote format, would you take the courses you are enjoying the most in the remote format?	Yes	35.2%
	No	38.4%
	Maybe	26.4%

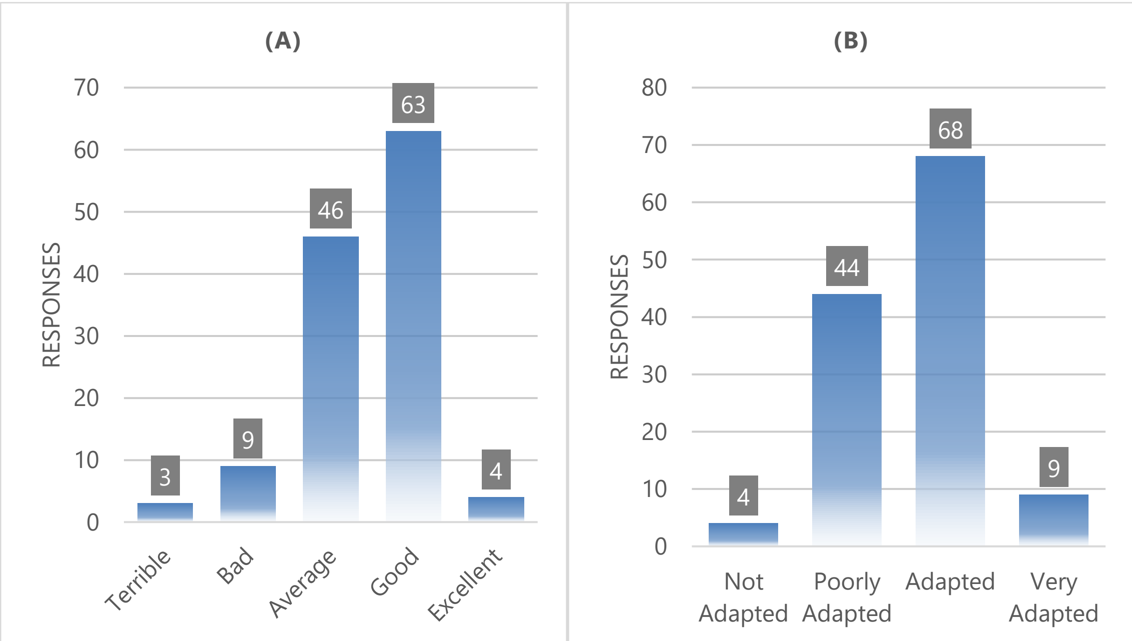

Figure 1. Answers from Questionnaire 1: Overall Student Performance (A) and Adaptation to Methodology (B).

The overall student performance in the remote courses is presented in Figure 1 (A). The students consider it as average (36.8%), good (50.4%), or even, in some cases, excellent (3.2%). Few participants indicate a bad or terrible performance. By the results presented in Table 1 and in Figure 1 (B), even though the transition was fast, the participants from Civil and Environment Engineering degrees of UnB, in their majority, feel adapted to the methodologies applied by professors (54.4%) and consider their performance at least in at average level. However, the students' perception of good performance may not reflect satisfactory learning quality. ERLP had not been previously tested in these courses. More studies should be carried out in the future with qualitative and quantitative perspectives. Silva et al. (2016) stated that the quality of teaching through the exclusive use of virtual platforms is doubtful and must be constantly evaluated and supervised.

Questions 1 and 2 related to the number of activities and assessments evaluate students' stress conditions. About the number of activities proposed in the courses, 40.8% believe that the amount is inadequate and 7.2% very inadequate, almost half of the responses. This fact is highlighted in the 29 answers to an optional question. The students commented that remote classes are more exhausting than face-to-face, and there was an increase in the workload assigned by each course during the ERLP. Due to the use of assignments and seminars as an evaluation criterion associated with a short deadline.

Despite the comments about the overload of activities, the assessments are consistent to most students (69.6%). This result aligns with students' perception of performance. Less than 10% of the responses consider the assessments little consistent with the classes. In this way, even with the rapid transition to the ERPL, professors successfully made compatible the course program with the problems proposed in assessments.

Moreover, as the teaching format has changed, many students miss the spirited debates about the contents. Surmacz and Lopes (2018) made a study about debates in classes. The authors state that classes with the absence of questions and debates become tiring and without knowledge exchange, being only expository. On the other hand, some students pointed out the advantages of the ERLP since there was no commuting time to the university. Thus, they could dedicate themselves even more to the courses.

About the courses' format, it is noticed a similar distribution among the alternatives presented in Question 3. Even though students classify their performance mostly as good in the ERLP, the face-to-face activities encourage more interactions. Also, there is the possibility of implementing practical workshops as a learning strategy and technical visits, which enriches the students' experience.

Many students in the optional question suggest using hybrid methodologies, with one part of the course as in-person and the other remote. This opinion is aligned with RL principles, in which there are synchronous and asynchronous activities throughout the teaching period with the application of face-to-face tests to evaluate learning (Minha Biblioteca, 2020).

3.2 Professors' Questionnaire

From the application of the method presented, 36 answers were obtained from professors of the Environmental and Civil Engineering degrees of UnB. The results are presented in Table 2 and Figure 2.

Table 2. Answers from Questionnaire 2: Professors' Perception of Remote Teaching Techniques.

Question	Answers	
(1) The course is:	Theoretical	52.8%
	Practical	16.7%
	Theoretical and Practical	30.6%
(2) Do you have any previous experience with RL?	Yes	13.9%
	No	52.8%
	Partially	33.3%
(3) The classes were:	Synchronous	44.4%
	Asynchronous	8.3%
	Both	47.2%
(4) Regarding the activities planned for the students, what level of changes occurred in relation to the face-to-face format? (Scale 1 to 5 - little change to a lot of change).	1	11.1%
	2	19.4%
	3	27.8%
	4	25.0%
	5	16.7%
(5) Regarding the performance of the students in the course in this period you consider that:	Improved a lot	0.0%
	Improved	19.4%
	Remained the same	30.6%
	Worsened	19.4%
	Got much worse	2.8%
	I cannot evaluate yet	27.8%
(6) If you had the option to choose between a face-to-face and a remote format, you would teach this course in either way:	Totally presential	38.9%
	Totally remote	5.6%
	Hybrid (one part remote and one part face-to-face)	55.6%

The number of courses offered by the department during ERLP was 85. There are professors responsible for more than one course. The answers obtained represent professors responsible for 36 courses, about 42% of the total. According to Question 1 in Table 2, most of the courses are theoretical only, more easily adjusted to the remote format since it does not require laboratory or field sessions. Furthermore, 16.7% are practical only, which are the most challenging courses to adapt to the remote format quickly.

An important observation that should be considered is that more than half of the professors, until the pandemic period, had no RL experience, as shown with Question 2 results. From the 36 responses, 47.2% indicate previous or partial RL experience. A group of professors and students was created to share lessons learned with RL and evaluate the perception of both sides on the ERLP.

As half of the professors did not have previous RL experience, they had to adapt to the new tools to implement their teaching methodology successfully. This adaptation was well seen after the ERLP in Question 6, 55.6% of the professors would like to mix face-to-face classes with remote classes in a hybrid format, and 5.6% would like to make their course entirely virtual. In this way, in-person activities would gain a more practical aspect with less expository content, easily adapted to the remote format in an asynchronous mode.

There were three alternatives about the classes: Synchronous, Asynchronous, or Both (synchronous and asynchronous). In this aspect, it can be observed with Question 3 that only 8.3% of the professors chose to hold only asynchronous classes, which is an outstanding result. It means that 91.7% of the professors are still connected, even virtually, with their students. Veiga et al. (1998) state that synchronous classes are more spontaneous than asynchronous ones. These classes have greater group synergy. Instructors are free to interact with students in an online session by speaking, presenting demonstrations, addressing students via video, and providing quick feedback.

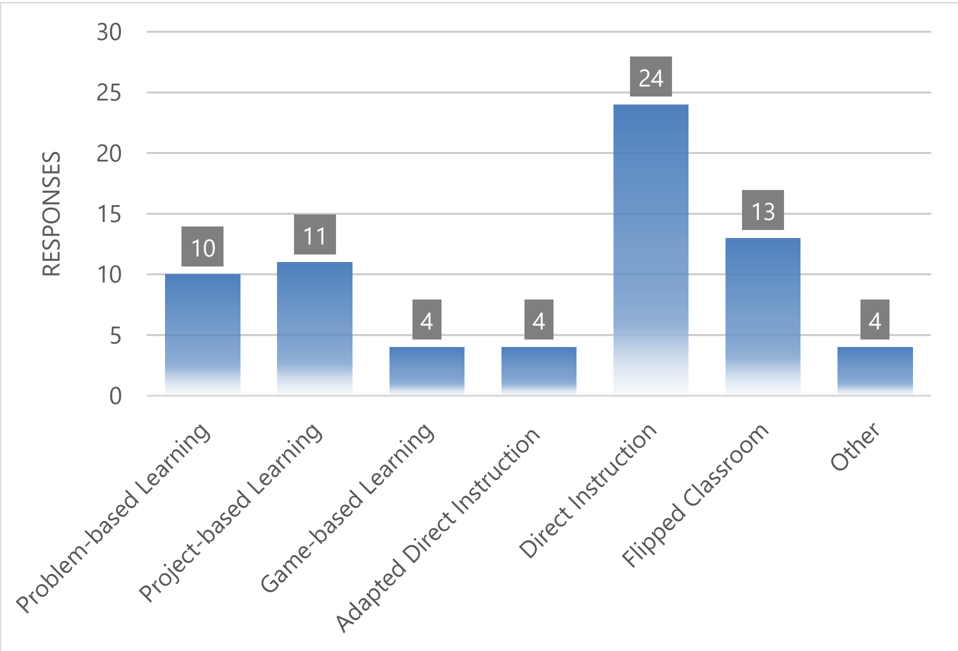

Figure 2. Answers from Questionnaire 2: Teaching Methodologies applied by Professors

Most professors chose to adjust the direct instruction methodology or use it purely in the virtual environment without any modifications. Also, some professors use active teaching (AT) methodologies, such as problem- or project-based learning, gamification, and flipped classroom. AT methodologies are student-centered and contribute to reducing stress, according to Cabanach et al. (2016). It is important to emphasize that the participants use more than one teaching methodology in their classes. Consequently, the number of responses obtained is higher than the number of participants in the survey.

The courses' changes related to planned activities had a uniform distribution in Question 4, with slightly higher grades 3 and 4. Professors had to adapt the activities to the remote format, and this question indicates that this process was different for each course. Especially for the most challenging courses to adapt, those with field and laboratory sessions, this type of experience was covered with photos, videos, and software simulations. In general, most courses had significant changes.

The same behavior is observed about students' performance from the professors' perspective in Question 5, 30.6% state that remained the same and 19.4% improved or worsened. This evaluation is aligned to the students' perception, as most indicated a good performance in ERLP. Courses with practical activities criterion noted less participation of students in classes, resulting in a worsening of performance. The questionnaires' application occurred in the mid of the ERLP. In some courses, especially with evaluation exams near the end of the period, professors could not notice a change in student performance.

The platform most used in the ERLP was Microsoft Teams, made available by the institution. It is possible to hold synchronous and asynchronous classes and even evaluations through the platform. The professors' second most used platform was Aprender/Aprender 3, which was also made available by UnB. The most used evaluation criteria were assignments, seminars, and class participation, according to the survey.

By analyzing the answers from both questionnaires, we can highlight a few courses with greater acceptance. Most of them are exclusively theoretical and adopt a direct instruction methodology adapted to the virtual context with innovative methodologies. The primary purpose is to make the learning process more collaborative, as discussed in the students' questionnaire results. In these courses, the professors had no previous experience with the remote format. The classes had synchronous sessions and asynchronous content, which substitutes the in-person laboratory practices and field visits.

The courses with the highest student approval, amongst the 85 courses analyzed, use active methodologies, like project-based learning and flipped classes, to motivate students to construct knowledge collaboratively. In these courses, professors' attitude towards this new version of teaching was praised by the students since they offered time for debates in their classes and were accessible to answer questions.

During the first semester of classes in ERLP, there was a significant increase in assessments through assignments, exercises, and projects intended to help students stay focused on their courses. However, when most of the courses opt for a single evaluation criterion that requires more time from the students, the students reported another problem: the overload of activities required in the courses.

As previously presented, students indicated they are more tired during ERLP. Galasso (2014) points out possible reasons for exhausting in RL: the insufficient mastery of ICT (Information and Communication Technologies) by both the student and the professor, the inadequate preparation of students for an online course, the difficulties of student interaction with their tutors, colleagues, and technologies, the inefficient management of study time, the excess of activities related to the content of the subjects taught and expectations. These points contribute even more to a high tax of dropout and frustration of students in this learning format and consequently a worse performance.

In courses with lower acceptance among the students, the main complaint was the number of activities proposed and the time committed. In all cases, the professors used three or more evaluation criteria, with tests and numerous assignments. The direct instruction methodology also stood out in these cases since the expository classes were mainly synchronous. In all cases, the professors' perception was that the students' dedication time increased in the ERLP.

4 Conclusions

With the results of the questionnaires and the crossing of responses, this paper was able to bring the results of a survey about the perspective of students and professors regarding the Emergency Remote Learning Period (ERLP) in the Department of Civil and Environmental Engineering (ENC) at the University of Brasilia (UnB). Professors can observe where the students well accept their methodologies, and in return, the students can see more clearly what is expected by the professors.

In general, the students consider themselves adapted to the professors' methodologies and that the evaluation criteria used are consistent. Moreover, most participants indicate good performance in the ERLP. Meanwhile, it was also pointed out that the remote classes are more exhausting when compared to the face-to-face model and that there was an overload of activities in specific courses.

From the professors' perspective, it was observed that it was necessary to redesign the activities, which required effort since many professors had no experience with online classes. The most used methodology was the direct instruction method, the same applied in the face-to-face format. Learning evaluation was done mainly through assignments, seminars, and class participation.

The purpose of the research was not to evaluate or qualify the methodologies implemented by the professors. It sought to measure the teaching models' acceptance among the academic community of the Environmental and Civil Engineering degrees of UnB during ERLP. Highlighting methodologies that were better accepted by the students or brought more benefits to the professors. This way, the lessons learned can be implemented in future applications and contribute to EE practice.

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Development and application of a teaching-learning model among eduScrum and active learning methodologies

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Abstract

The present work addresses the structuring and application of a teaching-learning model, which explores the interface between eduScrum and active learning methodologies, in particular Project-Based Learning and the Flipped Classroom, in teaching-learning management of projects. Both eduScrum and active learning methodologies bring key concepts such as regular feedbacks, prioritization of content applicable in practice and centralization of the process in the student. Thus, a framework of 5 sprints was structured with 6 classes each to use both approaches in a complementary way, detailing step by step during the research. The application was carried out in the discipline Project Management and Multidisciplinary Teams in the semester of 2020/1, offered by the Department of Civil and Environmental Engineering at the University of Brasília. The steps involved in the project were: literature review; application of a questionnaire to identify the requirements of the discipline in the students' view; structuring the model and the necessary adaptations for remote education, depending on the pandemic caused by the Coronavirus; application and evaluation of the developed model. The implementation of the model throughout the semester was highlighted by the positive reception by the students and the relevance of the projects developed by the groups and allowed to identify opportunities for improvement in the dynamics of the activities, in the schedule and in the evaluation method. In the end, an anonymous questionnaire was obtained with the students who took the course a Net Promoter Score of 82 points and an average satisfaction of 4.5 on a scale of 1 to 5. These results points to the potential of using this method of non-traditional teaching in engineering education.

Keywords: EduScrum, Project Management, Project Based Learning, Flipped classroom.

1 Introduction

Worldwide spreading from the book "The art of doing double in half the time", by Jeff Sutherland (2014), Scrum is a methodology that, although initially created for the development of software, gained space for its application in several industries and services, including education. In this sense, eduScrum (Delhji et al, 2016) is an alternative to the traditional teaching / learning model, focusing on iterative, transparent, and agile learning, with successful experiences in different educational contexts.

At the same time, in recent years there has been a growth on the part of higher education institutions in the application of new concepts and learning methods in engineering education. It is a demand from the market and from the students themselves, by more dynamic, applied, and participatory classes, to acquire the skills and competencies necessary for the profession. Thus, Active Learning has become the focus of discussions around the world (Filho et al, 2019).

In this sense, the present work aims to use the synergy and similarities between eduScrum and active learning methodologies to optimize the results of teaching in engineering, through learning cycles and direct interaction with students. Thus, a model was developed and applied involving both eduScrum and active learning methodologies in the semester 2020/1 in the discipline Project Management and Multidisciplinary Teams, at the University of Brasília.

2 Theoretical Framework

The theoretical basis for structuring the interface that was applied in the discipline was based on three topics: scrum / eduScrum, Flipped Classroom and Project-Based Learning.

2.1 Scrum / eduScrum

Scrum is a project management methodology popularized since 2014. Among its characteristics, flexibility stands out, which works by defining an incremental process that can be applied in processes and projects of different sizes, using adaptability to ensure constant evolution. In his book, Sutherland (2014) presents three pillars that support Scrum: transparency, inspection, and adaptability. The application of these allows the user to deliver creative solutions based on the constant adaptability and learning process, with the importance of each pillar reflected in the team's roles, artifacts and events that characterize the methodology.

In the educational context, Scrum has been adapted for application in teaching, with experiences at different levels of education and countries. According to Delhij et al (2016) eduScrum is a light model, easy to understand and difficult to apply, in which students can solve problems to achieve learning goals and objectives, based on autonomy, teamwork and transparency, guiding the student with a focus on “what to do”, not “how to do”. The eduScrum team is formed by the teacher (product owner), students and the Scrum master (role played by a student). The main events foreseen in the application of the model permeate the sprints or learning cycles, namely the planning meeting, the stand-up, the review, and the sprint retrospective (Delhji et al, 2016).

2.2 Flipped Classroom

The Flipped classroom is an active learning model used at different educational levels, which gained notoriety from the publication of the book Flip your classroom: reach every student in every class every day (Bergmann and Sams, 2012). In general, the Flipped classroom consists of a methodology in which students prepare the theoretical content prior to the class and develop activities such as exercises, which are normally homework tasks in the traditional model (Filho et al, 2019). Your process can be classified into three stages: pre-class, class, and post-class.

In the pre-class, the teacher guides and provides materials so that students can have a first contact with the topic to be addressed, so that the student lists doubts and questions. During the class, the teacher must then stimulate activities to condense and clarify the content, such as synthesizing, analysing and debating, using different strategies for optimizing learning. The content base previously obtained by the students allows the teacher to provide a moment of real learning in the classroom, in addition to the development of other student skills in parallel with the technical content of the discipline, such as teamwork, argumentation and oratory. The evaluation process can also occur, naturally, at the time of the class or not, using different strategies such as seminars, assignments, or quick tests. Finally, the post-class consists of the student revising and extrapolating the content, for example with applications in his daily life and in other areas of knowledge (Filho et al, 2019).

2.3 Project-Based Learning

There is a wide variety of research that addresses the Project-Based Learning (PBL), due to the different definitions found and the lack of universal acceptance (Thomas, 2000), so that there are also several models for its application. In short, Project-Based Learning is an active learning methodology based on real everyday situations (Pereira, Barreto and Pazeti, 2017) (Bell, 2010) (Thomas, 2000). This proposal seeks to bring not only technical knowledge, but also skills such as problem solving, investigation and decision making, based on the guidance of a teacher (Thomas, 2000).

Five aspects define the PBL: the resolution of the problem can be proposed by the students themselves; the initiative to solve the problem comes from the students and requires integration between educational activities; a final product is delivered, consistent with the initial problem; the solution to the problem is usually developed as a project; the teacher does not exercise an authoritarian role, but as a consultant to the teams that will develop the project (Pereira, Barreto and Pazeti, 2017).

3 Methodology

This is an Action Research carried out in the discipline of project management and multidisciplinary teams during the semester of 2020.1. We opted for this methodology because it converged the opinions of a teacher advisor and the research student who experiences the educational experience. Still, according to Tripp (2005), Action Research presents activities in both the practical and research areas, in addition to being innovative, participatory, interventionist, problematizing, documented and deliberate, some of the characteristics that differentiate it from other investigative research, such as routine practice and scientific research.

To this end, the work was organized in four main stages: exploration of the project's theme, in order to raise the main aspects to be addressed and to support the discussions and solutions presented; review of the existing course, based on the literature and on the demands discussed with the guiding professor for teaching project management; application of the proposed model of learning in a course of the Civil Engineering at the University of Brasilia in the second semester of 2020; analysis of the results obtained, in addition to the necessary adjustments according to the progress of the discipline's application.

The exploration of the project's theme consisted of an exploratory research, supporting the discussions and solutions through books, articles, and other related works. The main topics to be addressed, according to a previous survey, were eduScrum, learning methodologies and project management.

The review of the existing course consisted of elaborating and formalizing a model that used the lessons of the bibliographic review to meet the demands identified with the students. In this sense, an online questionnaire was carried out to collect the requirements with the students. Based on this understanding, the learning methodologies to be adopted and the structured interface between eduScrum and the activities provided for in the course plan were chosen, in addition to the identification of the recommended bibliographies and the structure of the project to be developed in groups by the students. This stage ended with the elaboration of the course's plan.

The application of the reformulated discipline occurred in the first half of 2020, remotely, due to the world pandemic and the interruption of face-to-face activities by the University of Brasília. Initially, an expectations questionnaire was collected from the class participants and, at the end of the semester, again, to compare the results. During the activities, the teacher acted directly, leading the class, while the other researcher was a student of the class, taking part in the activities as a member of one of the groups. In addition, a diary of the perceptions of both was made during the course, which was reviewed and discussed at the end of each sprint, in order to propose improvements even during the course of the school semester.

Finally, at the end of the class period, the analysis and consolidation of the data obtained was carried out, evaluating the satisfaction and results of the students who attended Project Management and Multidisciplinary Teams.

4 Model development

4.1 Requirements gathering and identification of the existing interface

Prior to the beginning of the enrolment period at the University of Brasilia, already having the initial hypotheses of the model to be proposed for the discipline of Project Management and Multidisciplinary Teams, the requirements were surveyed with the students of the department through a virtual questionnaire disseminated on social media.

The questionnaire was structured in some sections, being quick to complete in order to obtain a greater number of responses. The first section tried to characterize the sample, identifying the course, semester, gender, and age of the research participants. Then, questions were asked related to access, both in terms of infrastructure for remote classes, as well as the availability of time to take the course. In addition, questions were structured in relation to the students' previous experience with active learning methodologies and the investment they expected to make when taking an optional subject, in the case of extra-class time.

Finally, statements were structured to be evaluated by students according to the Likert scale, related to the initial hypotheses, in order to understand the value perceived by the participants in active methodologies, project management and behavioural skills, themes to be addressed in the discipline.

In total, 68 responses to the questionnaire were obtained, predominantly by the Civil Engineering and Environmental Engineering courses. The main answers that guided the research were the time of dedication expected by the students and the main aspects that add value in a discipline, being these with their respective scores on a scale of 1 to 5: multidisciplinary (4.50), addressing team management (4.53), addressing real situations (4.79), addressing project management as a whole (4.57) and develop complementary skills (4,51).

Parallel to the application of the questionnaire, the researchers worked on identifying the interface between eduScrum and active learning methodologies, mainly Project-Based Learning and the Flipped Classroom, which were selected for application in the first restructured version of the course. The objective was to identify the similarities of the proposals, in order to allow their optimization during the semester. Figure 1 illustrates the main considerations made.

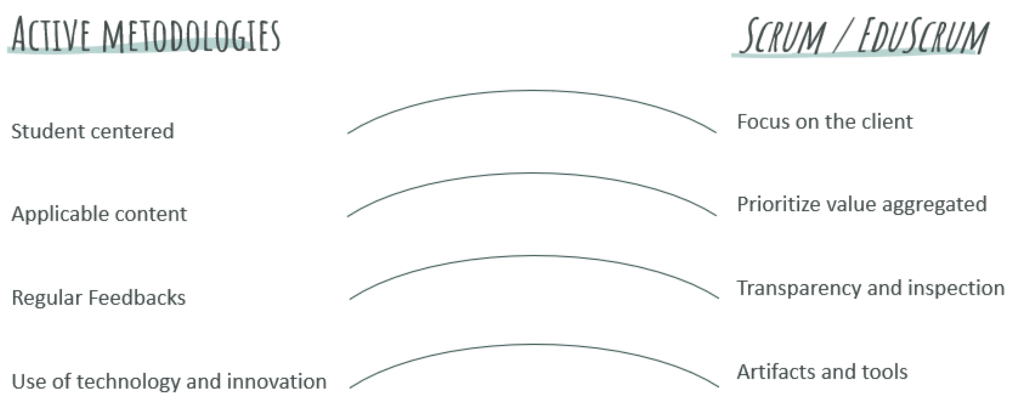

Figure 1. Interface between active methodologies and eduScrum.

4.2 Structuring of the Discipline Proposal

Initially, it was decided to maintain the discipline with 4 class hours per week, divided into two classes, for a total of 15 weeks of the academic semester, a model that had already been applied in other semesters. Based on this planning, a preliminary schedule and work plan was prepared. In addition, the class was limited to a number of 20 students.

Then, the weeks were divided into sprints, in order to guarantee the characteristics of eduScrum and the educational objectives. All planning was carried out previously, but later validated, in the first sprint, together with the students. In this sense, we opted for a collaborative process, so that the first sprint mainly addressed the alignment of expectations and objectives, allowing the prior planning to be adapted according to the class that is taking the discipline in the semester in question, as long as it meets the needs of the students' minimum requirements foreseen by the teacher.

The discipline was then divided into 5 sprints of equal duration, to facilitate the control for a first experience and to establish a modular and replicable structure for courses of greater or lesser duration. It is important that each of these sprints has the minimum events planned (planning, division of tasks, stand up, sprint review and retrospective) and a clear objective.

a) Sprint I (introduction): the first cycle of the course is focused on receiving students and adapting to the methodology, in addition to aligning expectations and work agreements. The idea is to address some initial project management concepts to contextualize students, but also to present the Scrum approach, as it will be necessary for the development of the course. The planned deliveries are the course plan, adjusted according to the agreement between students and teacher, and the project contract, with the rules of coexistence, deadlines and other agreements signed by the group.

b) Sprints II to IV (development): the development cycles consist of the main technical aspect of the course, in fact addressing the contents foreseen for the discipline and structuring the learning with the active methodologies. The order of presentation follows the logic of a project, using the conventional flow (beginning, planning, execution, monitoring and closing), with some topics in advance to facilitate coexistence and group work, such as communication management. The planned deliveries are related to the content covered in the classroom, applied to the discipline project. Thus, there is a parallel between theory and practice and knowledge is solidified within smaller cycles and close to the students' reality.

c) Sprint V (closure): the last cycle aims at evaluating and closing the discipline, in addition to addressing some additional content, such as project management references. Both its delivery and its development are based on the closure of the discipline project and the presentation, to formalize the conclusion of the "contract" established in the first sprint. It is important to emphasize that this cycle addresses not only the assessment of the teacher to the students, but also the self-assessment of each one and the retrospective of the entire project, in this case, of the school semester.

Figure 2 consolidates in a simplified way the structure adopted for the course.

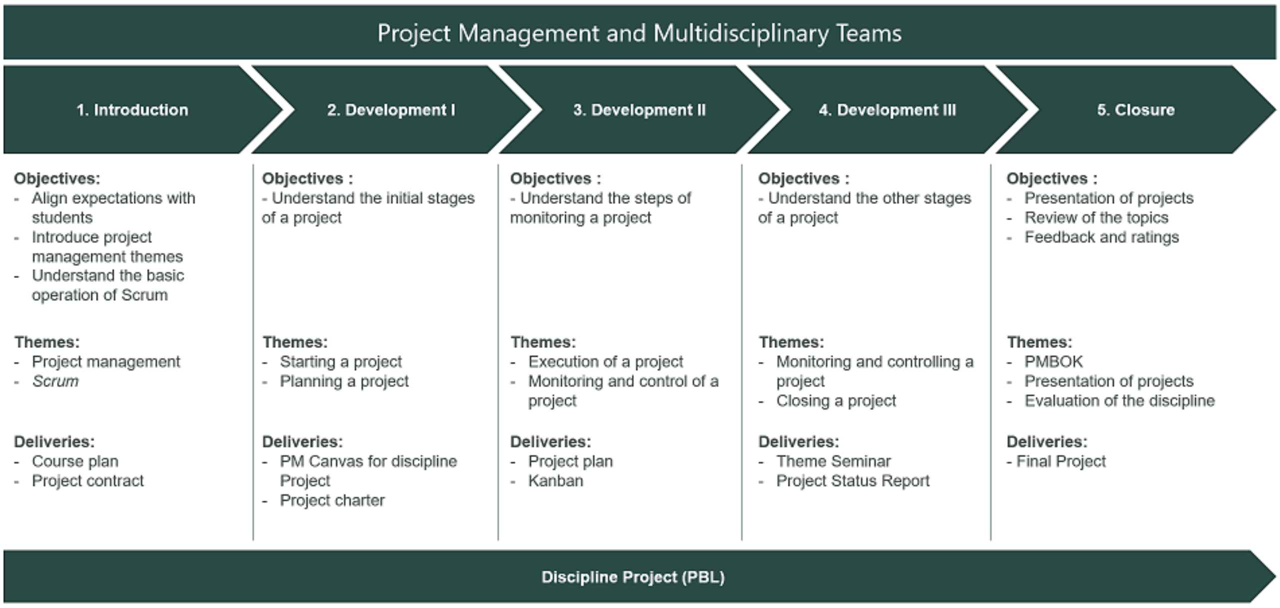

Figure 2. Basic structure adopted for the course.

Understanding the sprints in a macro way, the detailed approach for the 3-week cycles is presented. As already mentioned, the idea of being fixed-size cycles facilitates both the organization, as well as the planning and execution of sprints, adopting a simpler structure that is repeated during the development of the semester. In total, there are 6 classes of approximately 2 hours in duration:

a) Lesson 1: the first class of each sprint presents the objective of that cycle, proposes goals and deliverables, and allows students to plan. It also begins to address the concepts that will be developed;

b) Lessons 2, 3 and 4: these 3 classes are the technical development of the project management content, aiming to bring the robustness and the concepts necessary both for the development of the project and for its day-to-day application;

c) Lesson 5: this is a planned class that has two main functions in the schedule: bringing an applied and complementary approach to project management, whether with the application of workshops or cases based on real situations or discussion of complementary skills for a project manager, as oratory and organization; or allow a break in the schedule, so that in the event of unforeseen events or holidays the main contents and events are not compressed, and this class may function as a replacement for some of the others;

d) Lesson 6: the sprint closing class, aims to recap and reinforce the main points covered, in addition to allowing the assessment of the cycle, either formally (punctuated activities) or informally (individual student discussion and reflection).

4.3 Necessary adaptations

After the enrolment period and given the context of remote classes adopted by the University of Brasilia, some adaptations in relation to the initial model were necessary. The main adaptation was the use of Microsoft Teams, made available by the institution for teachers and students, in the realization of synchronous classes. In addition, in relation to active learning methodologies, the initial proposal brought several options and uses, alternating between various methodologies. Since the objective of the course is not to explain active methodologies, but project management, it was realized that it would be very complex to switch between so many methods, decreasing productivity and losing the focus of the course. Thus, the Flipped classroom and project-based learning were selected exclusively as methodologies to be adopted this semester.

The Flipped Classroom was chosen because it is closer to the students' reality and feasible in classes with more than 15 students, as was the case. In addition, its remote realization is not impaired, so it was considered easier to perform than other options. Project-Based Learning, on the other hand, was adopted because in addition to being an active methodology, it allows the use of concepts learned in the discipline itself, of project management, and was one of the most relevant points when adding value in a discipline, according to the questionnaire presented previously. In addition, both methodologies were already used by the teacher responsible for the discipline.

Finally, other relevant changes in relation to the initial proposal were the format of the classes with external guests and the contents and ordering of some themes. In relation to classes with guests, due to being remote, more expository seminars were given, with themes related to project management, while in the initial proposal, workshops and softs skills courses were also foreseen. The themes, however, were reorganized in order to prioritize interpersonal relationships and organization, considered essential for students in such an atypical semester, facilitating their development and application from the beginning of semester.

5 Results

At the end of the course, an anonymous, self-administered, quantitative and qualitative questionnaire was applied to all students enrolled in the academic semester. Regarding the general degree of satisfaction of the discipline, all students scored grades 4 or 5, on a scale of 1 to 5, so that the general average was 4.47.

In addition, students also rated a scale from 1 to 5, the importance of some aspects of the discipline, such as the use of foreign literature, active methodologies, and seminars with external guests. Only “Use of foreign literature” received “indifferent” grades on the scale, while all other items were classified as “important” or “very important” by the students. It is worth mentioning the use of active learning methodologies, which obtained the highest number of grades “very important” among the evaluations, which shows a great acceptance of students in the proposed approach, as shown in Figure 3.

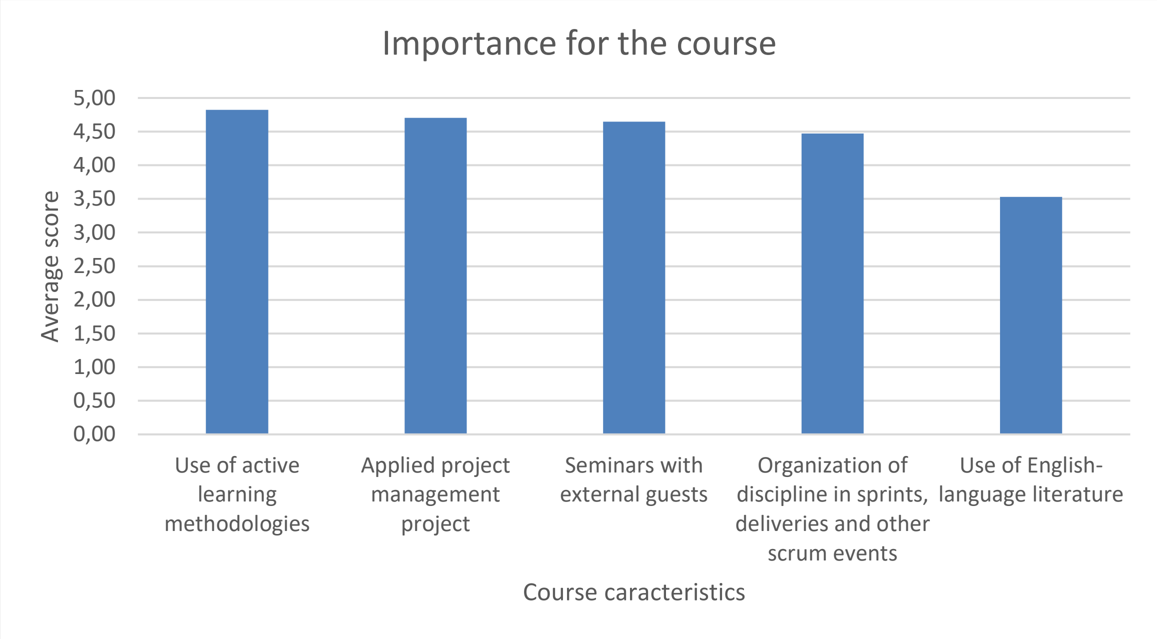

Figure 3. Answer about importance for the course.

Another point analysed were operational aspects of the discipline, such as the format of the classes, the scope of the project and evaluation methods. In this sense, the content covered, the discipline project, the evaluation methods and the bibliography used received the best evaluations. The format of the classes received some "Indifferent" notes, and the students commented that remote teaching has somewhat impaired communication and interaction at times, as shown in Figure 4.

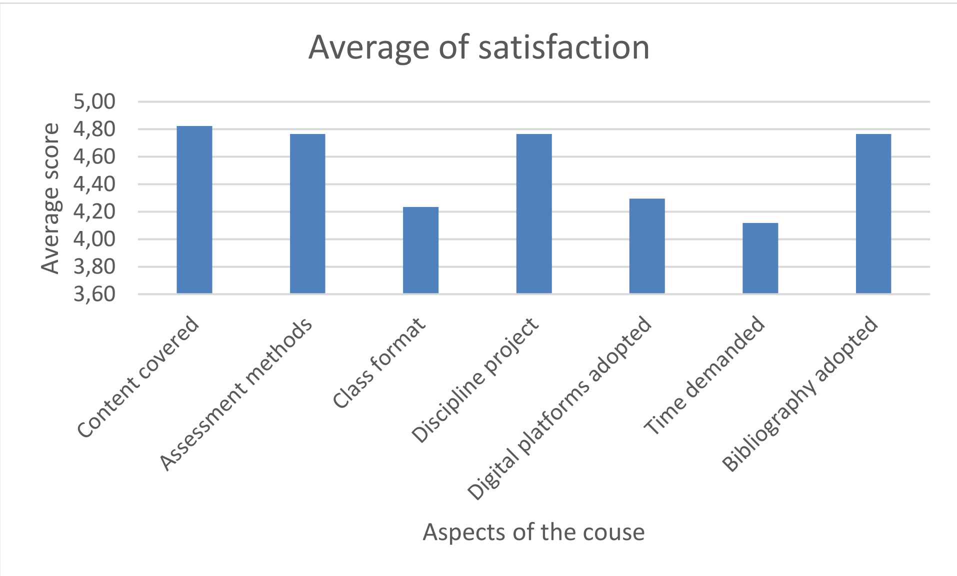

Figure 4. Answers about average satisfaction.

Finally, students were asked to answer the question "On a scale of 0 to 10, what would be the chance for you to recommend the GEPEM course to another person?", used to calculate the Net Promoter Score (NPS), as established by Frederick Reichheld, director of Bain and Company (Reichheld, 2003). After the calculation, the NPS obtained was 82. According to Bain and Company itself, this is already a note of the so-called zone of excellence, which indicates that the product or service is very well evaluated by customers and actively disseminated by them.

6 Final Considerations

In view of the developments, the interface between active learning methodologies and an agile project management method applied to education was satisfactory. The proposed model was applied within a limited context but managed to be validated and criticized in order to be better understood. It is noted that the satisfaction rate obtained by students with the discipline of Project Management and Multidisciplinary Teams was high, exceeding initial expectations. In addition, some key concepts proposed, such as active methodologies, the presence of external guests and the elaboration of real projects were extremely well received and approved by the students, with the main aspects being positively evaluated.

In relation to active methodologies, project-based learning proved to be efficient as an engagement factor and an excellent assessment tool, making deliveries clearer and allowing a direct application of the studied project management concepts. It is also believed that because it does not involve financial profits and the obligation to contribute to the University of Brasília, prerequisites defined by the professor in the elaboration of the projects, the dedication of the students with the result was greater.

However, during the process of applying and analysing the results of the method, points for improvement were identified. The biggest challenge encountered is to define structures, artifacts and tools that allow eduScrum events to be carried out within a shorter period of time and with a larger number of people, in order not to mischaracterize the method. Another point of attention is the definition of a schedule with time off, so that situations that may result in the cancellation of classes do not affect the deadlines globally. In addition, it is necessary to clearly define the evaluation methods and align them with the students, to obtain greater transparency in the process, one of the defining characteristics of Scrum. Finally, if the remote education scenario continues in the next semesters, it is interesting to evaluate the use of other collaborative platforms, in order to integrate less participatory students and bring greater homogeneity in the class.

Even so, the present pilot experience shows itself as a promising alternative for increasing student engagement and the use of active methodologies, in contrast to the predominant expository curriculum existing in engineering in general, possibly being applicable in other disciplines, both on-site and remote. It is expected, in the continuation of this line of research, to improve the proposed model and apply it to other contexts for greater validation.

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DesENCrenca: a PBL experience on Project Management education

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Abstract

This paper reports the experience of the students of Group 1 of the discipline Project Management and Multidisciplinary Teams ("Gestão de Projetos e Equipes Multidisciplinares – GEPEM – in Portuguese) developed during the 2020.1 academic semester of the University of Brasília. The GEPEM discipline uses active learning methodologies, focusing on the Flipped Classroom and Project-Based Learning. The project aims to improve the access of students of civil engineering and environmental engineering courses to the information of the subjects offered by the Department of Civil and Environmental Engineering and assist them in the process of assembling the grid of disciplines to be studied in the school period. For this, all stages of product development were carried out, from market research (via questionnaire and focus groups), to the delivery of a prototype. The team organized and worked in a format adapted from Scrum and used project management concepts learned in the classroom during the semester. The final product consisted of an interactive panel, fed in real time by questionnaires intended for students, in order to centralize information of interest to students, such as degree of difficulty of the subjects, evaluative methods and perception of effort demanded, assisting in the personal organization of students of civil and environmental engineering courses. During the process, it was remarkable the improve of productivity and direct application of the study in the classroom, so that all members of the group considered the discipline satisfactory and obtained high mentions in the evaluation by the teacher.

Keywords: Active Learning; eduScrum; Project Management; Engineering education.

1 Introduction

In recent years, the profile of students from engineering universities and that required by the labor market has changed, valuing experiences, soft skills and practical knowledge, in order to allow greater synergy between higher education and daily professional activities (Filho et al, 2019). Long, exhibition classes in crowded auditoriums are becoming less common, as institutions are forced to meet these demands and provide new engineering education. According to the National Curriculum Guidelines of Engineering Courses (2001), the trend is undergraduate courses with more flexible structures, which allow the future professional to have options for areas of knowledge and performance, also involving socioeconomic and environmental aspects for a complete training.

In this sense, active learning methodologies, characterized by its centralization of the process in the student, has gained strength around the world (Filho et al, 2019). Among the different practices that have been incorporated, project-based learning stands out because it has a clear affinity with the end of engineering activity, allowing an easy adaptation of both teachers and students.

Thus, in the discipline Project Management and Multidisciplinary Teams of the semester of 2020/1, offered by the Department of Civil and Environmental Engineering of the University of Brasília, the use of Project-Based Learning was adopted, among other methodologies. The discipline in question addresses varied topics in the context of project management, so that the concepts discussed were applied by the groups on a day-to-day basis, during the academic semester, based mainly on the PMBOK (PMI, 2017) and the book Getting Started in Project Management, by the authors Paula Martin and Karen Tate (2001), the main bibliographic references adopted in the course. During the semester, the students were divided into groups for the development, management and delivery of a real project. The prerequisites determined by the professor were that this project was not for profit and met some demand from the institution, faculty, or students of the University of Brasília. Thinking about it, the group identified the lack and decentralization of clear and objective information during the enrolment period of the courses of the Department of Civil and Environmental Engineering, hindering the organization of students and causing a fall in academic performance during the school period.

This article reports the process of identification, development and prototyping of a platform to gather and present information about the disciplines and extension projects related to civil and environmental engineering courses, nicknamed "DesENCrenca" by the students of the project team. It is a Project-Based Learning experience applied to meet the students' own demands, using the concepts studied in the classroom.

2 Theoretical Framework

The development of the project permeated two main themes: project management, because it is the main scope of the discipline and its application during the course; and Project-Based Learning, the main methodology adopted in the classes and the motivating fact of the project.

2.1 Project Management

According to the PMBOK (PMI, 2017) project is a temporary effort aimed at creating a single product or service. It may contain repetitive activities, but your delivery necessarily needs to be unique. Projects occur at all levels within companies and in everyday life, for example, when we face personal issues as projects to be completed. As for the temporary nature, it is understood that a project has a well-defined beginning and end, being closed, for example, with the delivery of objectives, exhaustion of resources or even by legal requirements.

Since the project can be understood as described above, some consequences of its implementation arise. The first is that it is an agent of change in organizations, as it lists and organizes activities that will make a difference at some level. The second is that it adds value to stakeholders, as it is motivated by meeting their interests, complying with legal requirements or even creating or improving some process (PMI, 2017).

Aiming to execute the projects efficiently, meeting deadlines and ensuring the results, there are tools and techniques that make up the project management. According to Karen Tate (2001), project management is then this set of tools, techniques and knowledge that produce better results, involving various topics such as team management, communication and risk management.

2.2 Project-Based Learning

Project-Based Learning is an active learning methodology based on real day-to-day situations (Pereira, Barreto and Pazeti, 2017) (Bell, 2010) (Thomas, 2000). This proposal seeks to bring not only technical knowledge, but also skills such as problem solving, investigation and decision-making, based on the guidance of a teacher (Thomas, 2000). There are different definitions found about Project Based Learning and also a lack of universal acceptance (Thomas, 2000), what infers in different ways of it apply.

Usually, a project developed on PBL is focused on solve a problem. Pereira, Barreto and Pazeti (2017) cite five distinct aspects to define the PBL: the resolution of the problem can be proposed by the students themselves; the initiative to solve the problem part of the students and requires integration between educational activities; a final product is delivered; the solution of the problem is usually developed as a project; the teacher plays as a consultant to the teams that will develop the project.

3 Methodology

Following the chronology of a project, its development began by identifying possible demands in the context of the University of Brasilia. A survey was conducted by the project team about the pains to be solved in the academic environment. Among them, the lack of information and the difficulty in organizing the school semester was considered the most impacted by the students of the group, especially those of the initial semesters of graduation. This is because it is necessary to reconcile extracurricular activities, compulsory subjects, internship and personal life.

A focus group was organized with students from other groups of the discipline itself with the aim of exploring this understanding and validating in a reduced context. The focus group was voluntary, being recorded for further analysis and interpretation.

Once the initial hypothesis was validated, through some adjustments and directions from the focus group, an objective questionnaire was elaborated to achieve a greater reach of students and confirm the existence of demand in a generalized way in the department and in the university as a whole. Among the answers, 96.6% of the students approved the structuring of a tool that centralized the information during the enrolment period.

Then, the development of the project began, using the tools and knowledge discussed in the room, for example the Kanban framework and the Analytical Structure of the Project. It is worth noting that the whole process was managed by the students, remotely, due to the context of the pandemic and the adoption of remote classes by the University of Brasilia.

According to Eric Ries in "The lean startup" (2019), a minimum viable product (MVP) should be used to validate its assumptions regarding the need of customers. Therefore, development ended with the presentation of the minimum viable product to the Product Owner of the project, in this case, the teacher. The platform was functionally structured, with fictitious information for validation, being presented together the learnings of the development process and the next steps for product consolidation and release to the public.

4 Project Development

From the initial understanding and validation with the focus group, the answers of the questionnaire were collected to identify the main aspects that the platform should cover. In this sense, it was noted the need to limit the scope to the Department of Civil and Environmental Engineering of the University of Brasília, depending on the available time of development and the amount of information needed. Also based on the questionnaire, the main information that should be gathered was determined: official information of the disciplines (made available by the department when publishing the list of offers of disciplines) and reports of experience of the students, describing aspects such as evaluative model of the discipline, difficulty and need for extra class dedication. In addition, the demand to incorporate the standard flowcharts of disciplines of each of the courses (Civil Engineering and Environmental Engineering) and information related to extension activities was identified, following the same division of official information and experience reports.

From the first definition of the scope, a PM Canvas was elaborated for the project, Figure 1, which provided a better initial organization and overview of the product, identifying its justifications and objectives, defining its requirements, stakeholders, benefits, risks, costs and restrictions, and delimiting the team, deliveries and timeline of product construction. Using PM Canvas, it was possible to study the feasibility and continuity of what would become delivery.

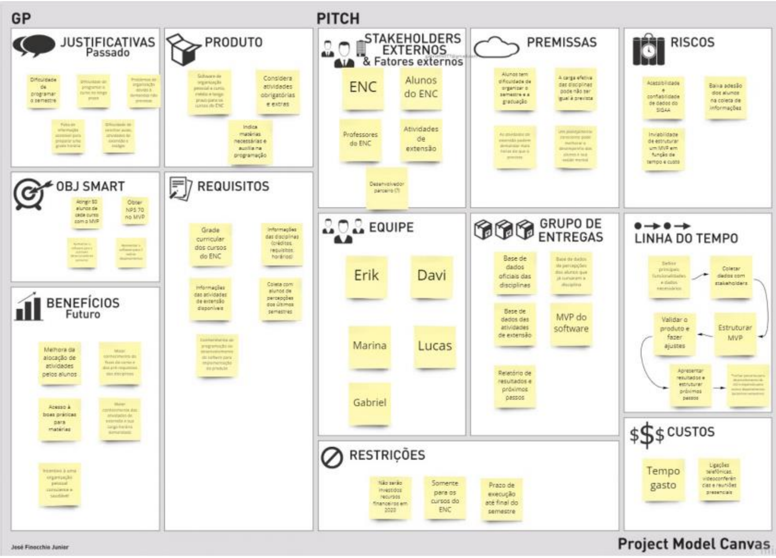

Figure 2. Project Model Canvas, in Portuguese.

Then, the necessary information was collected to make up the information panel. For official information, students used the department's systems and means of communication, such as the published enrolment offer list and SIGAA (student enrolment and monitoring system). The other information was collected with anonymous questionnaires with the students, so that the experiences could be consolidated in objective questions, facilitating the understanding and allowing the average sums of the values obtained. It is worth mentioning that, because they are personal opinions, in the questionnaire the group made it clear that responses offensive to teachers, extension groups, or considered inappropriate would be considered.

To monitor the activities, a spreadsheet was assembled using Microsoft Excel where they were assigned responsible and deadlines for the closure of each action. In class, the Scrum methodology was presented, so that the team chose to define deliveries in the form of Sprint fortnightly, each containing a package of actions and a closing meeting was held for team alignment, which made the process more agile and with great time gain. The team also opted for the use of the Trello application with the Kanban tool applied, so that it was possible to monitor the development of the actions during the Sprints in an easier way and without the need for many meetings, optimizing the working time, since the students who had other commitments and had little availability of hours beyond the class (Figure 2).

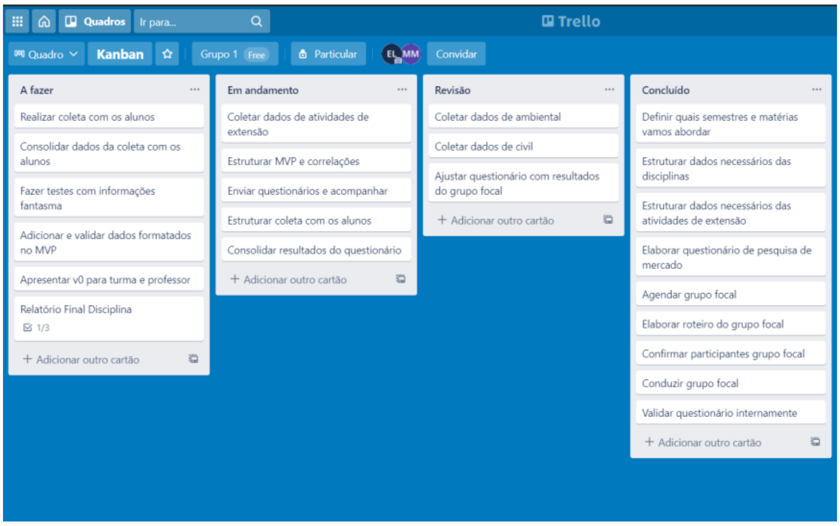

Figure 2. Trello of Group 1, in Portuguese.

In parallel, as the team matures, both in relation to productivity and in relation to the understanding of the project, and as taking into the concepts of project management were discussed in the classroom, of the project was elaborated, dividing it into three macro steps: planning, development and finalization of the, which in turn were subdivided into activities, and again subdivided into shares. The planning stage included two activities: research and data collection, sources and stakeholders, so that a Sprint was dedicated to perform all the actions of each one. The product development stage was also divided into two activities: structuring of the MVP and validation and adjustments, for which a Sprint was also designated for each. Finally, the last stage of product completion was divided into three activities: preparation of a final report, presentation of the product to stakeholders and structuring the next steps for the project, and as in the other stages, each activity was assigned a Sprint, but due to the closing period of the school semester, the period of the Sprints was reduced to one week. , In addition, a, survey of risks associated with each stage, incorporated into the same diagram in order to manage it and avoid development impediments.

With the understanding of the negotiation aspects in advance, the structuring of the prototype began. In this sense, one team member was allocated to centralize this activity, while the others finished collecting information and structuring the final report, consolidating the development process, difficulties, learning and next steps to complete the delivery. Such a report was determined as a formal delivery by the teacher, together with the prototype, in order to evaluate the performance of students in the discipline.

5 The Prototype

The platform used for development was Microsoft Power BI. This platform was chosen because it allows the creation of interactive panels, visually friendly and updated in real time. In addition, you can share the dashboard via link, and you do not need to download the app to view the information. This was a point of great importance to increase the reach of the product and allow its visualization using mobile phones and tablets.

The initial interface was subdivided into 6 menus (Figure 3), which direct to the functionalities, of which three were presented in the prototype, the information panels. The simulators were partially developed as a complement, aiming that the student could assemble hourly grid models, check the time needed to complete his graduation and calculate his academic performance on the platform itself. However, because they are complementary functions, they were defined as future scope, therefore disabled for initial testing.

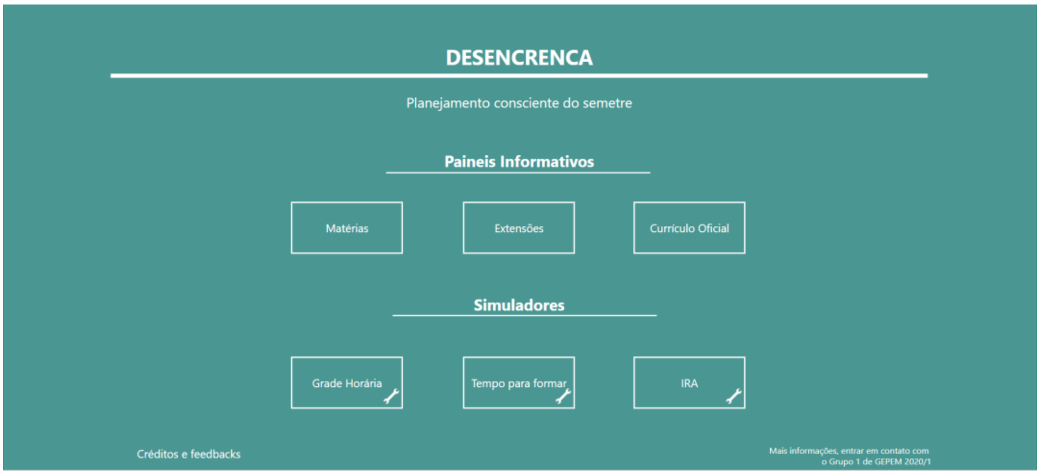

Figure 3. DesENCrenca main page, in Portuguese.

The information panels were divided between official information, information about the students' experience and a comparison of both data. In addition, the field "Tips and Comments" provides a brief report on subjective aspects of each subject or extension activity. On the side there is also a menu of navigation and filtering, in a way that directs and facilitates the experience of users on the platform (Figure 4).

Figure 4. Example of discipline information at DesENCrenca, in Portuguese.

Finally, it is worth noting that all pages allow access to online questionnaires that feed them, so that the user is redirected and can contribute to the collaborative database that feeds the system. As responses are being stored, an update has been scheduled so that the dashboard is also updated and can provide more current and accurate information.

6 Conclusion

At the end of the semester, the students presented the product and the report for evaluation of colleagues and teachers. The prototype was enthusiastically received, both by graphic choices and consolidated information, although incomplete.

Thinking about the experience of developing the project, the group noticed a maturation and improvement in productivity during the semester, as the theoretical discussions were presented in the room. The direct application of the concepts for the elaboration of the tools allowed greater clarity in the priorities and understanding of the proposed scope. Still, the greatest perceptual gain was the application of the concepts of agile methodology, so that the structuring of internal deadlines, adoption of Kanban and sprints with fixed deadlines increased productivity and ensured the delivery of a minimum viable product beyond initial expectations. All members of the group received the maximum mention in the discipline, "SS", and considered the discipline of great practical utility and aggregator of tangible knowledge for professional life.

Thinking about the continuity of the initiative "DesENCrenca", the next steps include the development of complementary functionalities (simulators) and release for use in beta by students. In addition, from the collaborative databases built, it is possible to structure other panels for analysis, serving for example for the Department of Civil and Environmental Engineering to understand the students' view of the disciplines offered.

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Virtualizing Project-Based Learning: an abrupt adaptation of active learning due to the COVID-19 pandemic with promising outcomes

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Abstract

Project-Based Learning (PBL) is renowned as an active-learning practice that promotes the application of knowledge build-up through real-world and often open-ended problems. PBL has been applied as a methodology at the Engineering School of Lorena, at the University of São Paulo, through different courses over the curriculum of a typical Industrial Engineering student. The first of which is taken during their first semester, in which students must develop solutions for a given single problem through the weekly class meetings. The observations of the evolution of the activities throughout the years demonstrate that the collaborative and group activities act as exercises that develop transversal skills an engineer should possess. These courses have been applied since 2013 under continuous improvements through feedback from the many shareholders the courses present, including the students, instructors, and guest evaluators. The projects are mostly related to the Sustainable Development Goals for 2030. In a matter of a few weeks of classes in 2020, the COVID-19 pandemic forced a quick virtualization of the learning process, posing an unprecedented scenario for the students and the instructors regarding in special this course, which is based primarily on presential discussions and activities. The first weeks of class following the abrupt virtualization of activities were encountered with misinformation and lack of clarity on the adaptation of the activities. Fortunately, through rapid iterations, the adjustment process resulted in time invested by the students and classes with active discussion using the tools made available by the University. In this sense, this work aims to present the forced abrupt changes applied to this first semester course, highlighting the challenges faced and the positive outcomes obtained and observed by both the students and the instructor, making a comparison with the evolution of the course over the past years.

Keywords: COVID-19; Project-Based Learning; Virtualization.

1 Introduction

The challenges involving in recreating novel and adaptable strategies in the training the future generations of engineers often converge to the pathways leading to the roles of each participant in the classroom. The long-standing tradition of passive-oriented courses, with a unidirectional flow of knowledge, coming from the active agent in the classroom, i.e., the instructor, reaching the learners, standing as passive receptors of information is often regarded as a method that often fail to meet the majority of the objectives related to the learning process (Al-Zahrani, 2015). Among the strategies to overcome the obstacles to which traditional Engineering education is set, some active-learning strategies have been developed over the past decades with the main goal of transferring the flow of information within a classroom setting (Hartikainen et al., 2019). These methodologies address the students as the main characters, i.e., as active agents, of the learning process, making them responsible for gathering and working the process to build up knowledge.

The use of Project-Based Learning (PBL) as a practice to promote active-learning experiences has been built upon a wide array of successful cases based on real-world and challenging situations for both the students and the instructors. Since 2013, the Engineering School of Lorena at the University of São Paulo, Brazil, has been offering some courses with primarily teaching and learning practices based on PBL (Pereira et al., 2017). The career in Industrial Engineering at the same program, for instance, has three mandatory courses that students must take on their first, fourth, and seventh semesters of their twelve-semester program that are entirely based on PBL and aim to promote their learning through the development and prototyping of solutions for complex problems through the weekly class meetings. The evolution of the activities, coupled with the lessons learned over this eight-year frame, have led to some early conclusions that the learning of techniques and concepts that are directly related to the main technical competences one could expect from an industrial engineer is successful. Furthermore, our findings also demonstrate that the application of PBL in these courses served as a strong catalyst in the enhancement of transversal competences to the students, which often are disregarded, or at least not directly evaluated, in a traditional and passive-learning classroom experience.

These mandatory PBL courses are named Integrated Project in Industrial Engineering (IPIE) and are divided according to the technical complexity regarding the Industrial Engineering tools one should expect from a student at a given point in their curriculum. The first IPIE course, offered to first-semester students, is offered as an introduction to the methodology and its problem scope has been, over the last years, been based on the Sustainable Development Goals (SDG) for the year 2030, set by the United Nations. The projects developed by the first-semester students are, thus, often not strictly related to complex Industrial Engineering practices, but rather to diverse settings a typical freshman student can solve building up from previous experiences. Over the past years, a portfolio of IPIE projects were developed aiming to promote solutions to the matrices of renewable energy, to engaging youth in STEM (Science, Technology, Engineering, and Mathematics) practices, and more recently, in 2020, to promote solutions for the challenges of promoting accessible and effective education to children in school years in Brazil.

The calendar of Academic activities in Brazil typically starts off in late February and run for 15 weeks. In a matter of a few weeks of classes in 2020, the COVID-19 pandemic forced a quick virtualization of the learning process, posing an unprecedented scenario for the students and the instructors regarding in special this course, which is based primarily on presential discussions and activities that were not though prior that could be moved to a virtual setting. Fortunately, the adaptation of the classroom activities promoted results that demonstrated more time invested by the students and classes with active discussion using the tools made available by the University. In this sense, this article aims to demonstrate the forced abrupt changes applied to the PBL-intensive course of IPIE at the Engineering School of Lorena, illustrating the challenges faced and the positive outcomes obtained and observed by both the students and the instructor, making a comparison with the evolution of the course over the past years. Our findings, while still in the shadow of the uncertainties caused by the pandemics, are hoped to demonstrate some lessons learned for the years to come and the adaptation of online spaces of learning applied to courses that were not traditionally designed to be virtualized, hoping that the findings and the challenges could yield valuable references for the future learners and teachers in the post-COVID-19 era in Engineering education.

2 Scope and Research Methodology

The research method applied was the case study analysis. This qualitative method has an induction approach on the analysis of data and focuses on the description of the results and their meaning (Voss et al., 2002). The case study approach has an empirical approach, as this method approaches the investigation of a real phenomenon within the context of the real world, often considering the boundaries between the phenomena and the context are not clearly defined.

2.1 Structure, scope, and milestones of IPIE 1

IPIE 1 is taught for first-semester students enrolled at the Industrial Engineering program at the Engineering School of Lorena. Its structure is based on a 15-week semester with weekly meetings of 100 minutes each. The coursework from previous years, i.e., from 2013 until 2019, was entirely based in face-to-face meetings, while just the first two classes followed the in-person based structure. The structure of the first class was divided into segments dedicated to the introduction of the course and the division of the students into teams. Students were classified according to their academic experience, i.e., the students that had already been enrolled in other higher education courses, regardless of the career, were grouped separately from those that have never been part of any higher education activity, reaching a balance of two groups within the first classification and six within the latter. The first class was also useful for the students to know their group and to first familiarize with the theme of the projects for the semester session, which was based on the fourth Sustainable Development Goal, Quality Education. The instructor introduced the need to develop solutions to the problems facing the educational needs of Brazil, and later introduced the syllabus and the expected deliveries from the students during the coursework. The first of which was the concept of the project each group would be working at, which was presented in the second week of classes. Each presentation lasted for approximately five minutes, which was followed by feedback from the instructor. The third week of classes, following what was planned on the syllabus, did not occur, as it matched with the declaration of COVID-19 having reached a pandemic situation, which resulted in immediate response from the University to shut all in-person programs.

The virtualization occurred starting from an adjustment to the program at the fourth week of classes, using the Google Meet platform. The third class revolved within the theme of project management, which was introduced through Project Model Canvas by the instructor. The thirty-minute theoretical and practical exposition was followed by private meetings from each group using the virtual room setting of the learning platform. The following week was based on a similar structure but focused on the development of a research project. The expectations of the instructor were for the students to deliver a research project on the fifth class. The fifth encounter had as introductory framework the importance of teamwork, which was conducted by an external guest. The students were expected to deliver some tasks aimed at a better understanding of teamwork and how relevant this skill is to the project development. The sixth and seventh classes were dedicated to design thinking, also hosted by a guest, while the eighth class focused on oral and written communication skills. The eighth class was also the deadline in which the students had to deliver their preliminary report, in which they had to describe the prototype of what they were building in their projects. This was followed by the delivery of the prototype at the ninth class through a five-minute presentation, which was examined by four professors who were invited to serve as evaluators in this class.

The tenth and eleventh classes aimed at introducing the students to the norms of scientific writing. In the twelfth class, six students who were in their last year of studies gave a short presentation, allowing a roundtable discussion regarding some expectations of the first-year students. The thirteenth and fourteenth classes were based on meetings and feedback from the instructor, aiming at solving point issues in the projects that were supposed to be presented on the fifteenth class. The last week of classes was hosted by the instructor, having six professors serving as evaluators of each project.

2.2 Data collection

The data collection for the study was conducted via a questionnaire analysis on the last week of classes, through the analysis of the work reports, and through point observations of the instructor and other stakeholders that are not part of the members of the student groups working in the projects. The data collection from these multiple evidence and focal points allowed us the use of the triangulation technique, which consists of the analysis between the different data points. The triangulation of the data allows the visualization of possible converging and diverging points and opens the possibility of integrating quantitative points to qualitative data, and vice versa, according to Flick (2005).

The questionnaire contained a total of 28 questions based on a 5-point Likert scale: 1 (Strongly disagree), 2 (partially disagree), 3 (Neither disagree - nor agree), 4 (partially agree) and 5 (Totally agree), followed by an open-ended question aimed at a general feedback for the course (Table 1). Each questionnaire was answered individually.

Table 1. Questionnaire used at the last class of the IPIE 1 course in 2020.

Category	Question ID	Question
PBL	1	The use of PBL was a differential to IPIE1
	2	PBL concepts should be applied in other courses of my career
	3	The use of PBL methodology made my learning more motivating.
Teamwork	4	The team was able to properly assess the different points of view about the project.
	5	The team was agile in making decisions.

	6	My team researched about the project's theme in the most varied sources.
	7	The role of each member of the team was well defined and everyone worked in their proper roles.
	8	My team knew how to manage time well and fulfilled the proposed schedule.
	9	Everyone on my team was very understanding about the different ideas that come up in the execution of the project.
	10	All members of my team have shown themselves responsible for carrying out all the tasks assigned to them.
	11	My team's success was a function of the cooperation of all its members.
	12	The execution of the project improved the development of the interpersonal relationships of everyone on the team.
	13	All conflicts experienced by the group were overcome in a coherent and respectful manner.
	14	I realize that I learned to seek innovative solutions.
Personal Development	15	I had the initiative to collaborate with the team, even when I was not asked to do it by the leader.
	16	I realize that I have a greater critical sense that helps me to evaluate the different work proposals.
	17	I adapted easily with unexpected situations that arose during the execution of the project.
	18	My view on ethics has been improved in this project.
	19	The decisions that were made considered the impact of the project on the people involved.
Communication	20	The group's communication through the communication protocol was effective.
	21	My written communication evolved due to the project.
	22	My oral communication evolved due to the project.
Integration with other courses	23	I was able to verify a relationship between Calculus I and what I worked on the project.
	24	I was able to verify a relationship between General Chemistry I and General Experimental Chemistry I and what I worked on the project.
	25	I was able to verify a relationship between Reading and Interpreting the Portuguese Language and what I worked on the project.
Leadership and Tutor presence	26	The Tutor participated whenever called by the group.
	27	The contributions made by the Tutor were relevant.
	28	The leader knew how to lead the team very well.

3 Results

Following the assessment of the questionnaire at the end of the first semester of 2020, the quantitative results obtained are summarized in Figure 1. From a visual analysis, it can be observed an overall majority of results within the 4 to 5 range of the Likert scale, i.e., between partially agree and totally agree.

The response of the students regarding the acceptance to the PBL model is totally within the range of partially agree to totally agree, demonstrating that not only the methodology is a differential to the course and that it made their coursework more interesting, but also that PBL should be applied to other courses in their career.

These results, thus, validate the recognition by the students of the importance of PBL to their professional training.

Our assessment also encompassed the evaluation of the perception of the students regarding their responses towards two transversal competences, which were teamwork and personal development, and a technical competence, project management. The analysis of these responses revealed that the students had an overall good reception towards these values, as the majority were between the 4 and 5 range. The two data points with the lowest scores were found in question number 7, regarding the division of roles and the individual contribution to the overall success of the group project. This particular question possibly demonstrated some level of frustration from some team members that likely felt their work was unbalanced towards the average contribution to the objectives of the project. It is interesting to highlight the maturity of the students, especially taking into account that most of them have never been enrolled in a higher education career prior to enrolling to this course. The questions related to personal development were, again, all valued within the 4 to 5 range, demonstrating that the students felt that the methodology and the course project assisted them in building capacities related to creativity, critical sense, and ethics.

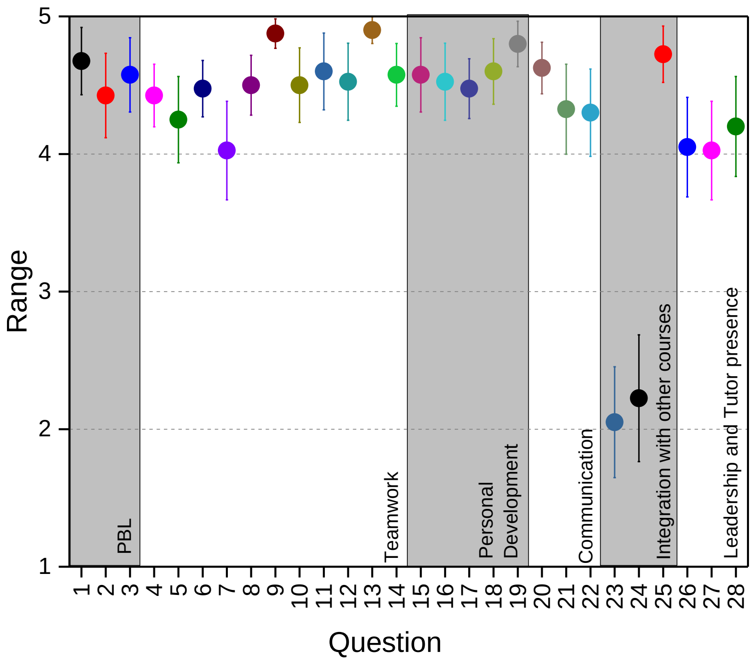

Figure 1. Scores of the responses and the range of their 95% confidence level on a 5-point Likert scale (n=40).

Two of the categories that should be carefully inspected herein are those related to leadership and to the integration of the concepts learned in IPIE 1 and other courses from their career, as these had lower scores in the evaluation. Regarding the leadership presence in the group, and the role of a tutor in the group activities, while the average score was within the 4 to 5 range, the confidence level of the range leads to perceptions within the neither agree nor disagree field. Some feedback given by the students in the open feedback question were that one "believes that a greater contact between the team and tutor would be beneficial to verify how the support is being given, and vice versa" and that there should have "more significant tutor presence in the activities". The points related to the integration with other courses were the lowest scored of the overall questionnaire, demonstrating that the students felt that the activities in the course did not converge to the courses in General Chemistry and Calculus 1, which are taken simultaneously, while the course in reading and interpretation of the Portuguese language was higher scored. It is important to highlight that the objectives of the latter are designed to be meant to give the students technical skills to read, to interpretate, and to produce technical texts in an Academic setting.

4 Discussion within the context of the abrupt virtualization

The forced and quick adaptation to the virtual setting of the course was given after two weeks of activities. The students, the tutors, and the instructor alike reached an agreement that the activities would be followed, until further notice, in a mixture of synchronous and asynchronous teaching and working modes. It is noteworthy to acknowledge that, given the circumstances, only seven of the forty open-ended responses mentioned anything related to the virtualization or the effects of the COVID-19 pandemics to the course. Some of these comments include:

> *"I believe that my experience in this course was complete. There were some limitations regarding virtual learning, nonetheless, the alternatives in which the course work were managed were valid and they led to a full learning experience and to the possibility of the project execution"*

> *"The transfer from the face-to-face to the virtual setting was well executed, and did not lead to significative losses in regard to PBL"*

> *"Even with the setbacks related to the pandemics, I believe the course was well planned and taught"*

While there was not any question in the questionnaire evaluating the perception of the students to the adaptation to the virtualization, it can be assumed that, while the process was forced in an abrupt manner, their response to the virtual meetings and to the adapted teaching mode was overall positive. We did not identify any negative feedback that was directly related to the adaptation process, and within a greater context, the instructor and the external stakeholders of the class felt the students were as engaged as, or slightly more engaged, when compared to previous years of the course. Our main assumption to this fact would be that this PBL course was among the few that allowed and encouraged students to actively participate in group discussions. We also relate the evidence regarding the proactivity of some students regarding the submission of the final product as a conference paper, which all were encouraged to be part of, even though it was not a mandatory part of the grading of the course. The students were encouraged to prepare a submission to, and to participate, at COBENGE (*Congresso Brasileiro de Educação em Engenharia*, Brazilian Congress in Engineering Education), taking into consideration that their outcomes were directly related to the implementation or development of technologies, products, or processes in the context of the SDG of Quality Education. We highlight two of these papers herein, which were published at the proceedings of the 48th COBENGE: (i) Youtube Channel to Forward Quality Education in Brazil (Gomes et al., 2020), and (ii) Educational Strategies and their Different Applications as a Complement in promoting Equitable Education (Mateus et al., 2020). Both papers were presented at a national level conference with a focus in Engineering Education, promoting an early entrance of undergraduate students to platforms dedicated to the promotion of science speaking and discussion.

Considering the scope within the classes were to be set, i.e., using virtual meeting platforms, Serhan (2020) demonstrated that the use of video conferencing classes allowed the students to have more flexibility, leading to easier interaction, better written communication, and effective use of multimedia. The same author, on the other hand, cites that the main advantages he found in the survey are related to distractions, to the quality of interaction and feedback, to technical difficulties, and to a poorer education quality. Within our observations, the students were excited to be and to participate in the virtual classroom, and overall lead to projects that were perceived by the instructor and the guest evaluators to be deeper and more complex when compared to previous years. In this sense, we were not able to distinguish the points related to poorer educational quality highlighted by Serhan (2020) given the considerations of this study. The feedback we received had some responses related to some of the advantages highlighted by Serhan (2020), that in this case, overlapped with the perception and the reception of the students to the use of PBL, such as:

> *"The classes were excellent. The use of PBL went beyond the expectations of what one learns in the course. I improved my proactivity, my communication, my teamwork, and overall, this course capacitated me as a professional and as a person. (...) I wish all the courses were like this."*

> *"This (virtual learning) experience was unexpected and good for me, considering the pandemic situation. I had the chance to develop some of my abilities, to work in team, and to think outside the box. (The course) was challenging, but with a lot of learning.*

Bao (2020) identified five impactful principles for effective teaching practices in online settings. These principles are based on the appropriate balance between an online design and the student learning process, on effective delivery processes of the instructional information, on an adequate support and feedback by the instructors, on effective and in-depth participation of the students in the learning process, and a strong and iterative contingency plan to work around unexpected incidents of online platforms. We believe that part of the promising results obtained at this case study can be related to most, if not all, of these principles. It should be highlighted that the objectives and the operational approaches of this course were not, and will likely not be, related to purely online platforms in the post-pandemic world.

To a larger extent, the replacement of face-to-face learning to virtual practices has been the basis of the emergency adaptation to adapt to the COVID-19 pandemic in many parts of the world, which led to an important debate to be made, based what will happen once we are able to effectively curb the sanitary crisis. While the move to the virtual setting has not been easy, there has been significant investments in overcoming technological barriers to support both students and faculty members. The findings of this work demonstrated that, PBL, given the appropriate conditions, could be adapted to virtual teaching and learning settings. We relate this success to a few points, which are all linked to the context of this study. The first of which being related to the timescale of the group analysis, which was in the first weeks and months of the pandemics, when the uncertain and naïve perception that the perduring effects of social distancing and isolation mechanisms would be, at most, a few months long. This could have caused a positive perception to the adaptation mechanism on behalf of the students, as there was a feeling that they soon would likely be in a physical setting again. The second concerns the size of the group. The student count was of 40 students, which was still appropriate for effective communication and feedback. The structure in which the class was set was transposable to a virtual setting, on a sense that the communication among the students was possibly as effective as when compared to the face-to-face design. The readiness and preparedness of the classroom participants, including the instructor and the students alike, was also a key factor that did not level off the baseline of an effective learning process, as highlighted by feedback comments considering that "*the transfer to the virtual setting was easy and effective, and the process did not leave anything behind*".

5 Conclusion

Considering all these aspects, our findings are found at an incipient phase of possible hybrid PBL classes in the future, with a few advantages considering the logistics of all the stakeholders involved, including external guests, and the multimedia of online platforms, We believe that, while this course could, theoretically, be converted to a fully online platform, some of the characteristics of face-to-face classroom settings can also benefit the learning and teaching settings, including the ease and rapidness of feedback on group activities, and the overall learning atmosphere of a classroom. In this sense, while this work is drafted still in serious conditions of the pandemics with unclear positions from the future of the classroom, we indicate that the valuable learning and advancements of PBL practices in a classroom can be adapted, and evolve, following the trends of good teaching and learning practices.

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Invest Game: Investiments in Startups in an Entrepreneurship Course

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Abstract

One of the great challenges in Engineering education is to open and foment the interest of learning about the technical core of each course and about complimentary themes that are relevant in the life of an engineer. Among the different approaches applied to implement novel learning methodologies, gamification stands as a promising alternative. This work aims to present Invest Game; a game created to be applied in entrepreneurship courses that have activities based on active learning methodologies. Invest Game aims to allow the learning about financial background and applications of startups through interactions among the students of a given class group within an Academic course. Invest game is applied in three rounds of investment, which are made by different teams that interact among themselves in each course term. This article, in these lines, explains step by step the logics and fundamentals of Invest Game and introduces a real case study of its application in an entrepreneurship course at the Engineering School of Lorena at the University of São Paulo in Brazil. In this course, the students were part of teams, which were named as startups with goals to create a business based on the Sustainable Development Goals for 2030 set by the United Nations. A questionnaire was applied at the end of the term, which demonstrates that, for the majority of the students, the game contributed to: (i) the development of competences about investment; (ii) the enhancement of the deliveries given across the course term; and (iii) the development of the startup they created.

Keywords: Gamification; Entrepreneurship; Investment; Startup; Active Learning Methodologies.

1 Introduction

High percentages of entrepreneurs in a country can be a reference of its economic development. The Global Entrepreneurship Monitor (Bosma et al, 2020) report presents an overview of entrepreneurship around the world. This report revealed that in 2019 the total rate of entrepreneurs in Brazil was 38.7%. It is estimated that about 53 million Brazilians (18-64 years) are involved in some entrepreneurial activity. The total early-stage entrepreneurial activity (TEA) rate was 23.3%; thus, Brazil occupies the 4th position in a ranking with 50 countries participating in the GEM in 2019.

Despite this high number of entrepreneurs, Brazil's National Entrepreneurship Context Index (NECI) is 4, thus placing the country as the 43rd in the ranking of 54 participating economies. The main factors for this classification are the tax and bureaucratic burdens, which are not favorable to the growth of companies, and the low emphasis on actions related to entrepreneurship in pedagogical projects (Bosma et al, 2020).

The same report also presents a general analysis of whether the new companies created in Brazil offer "new" or "old" products and services. The conclusion is that among new Brazilian companies, 98.4% do not offer new products and services. Only 0.6% of these new companies offer new products and services.

Amid constant changes and a future filled with uncertainty, job positions will increasingly demand adaptations and new standards. According to the World Economic Forum, new opportunities undergo rapid changes to meet the technological and economic needs provided by evolution. Like job opportunities, companies are also changing, and due to the great competitiveness of the market, they are increasingly looking for qualified and innovative professionals (WEF, 2020). Among these professionals are Engineers with solid technical backgrounds. Engineers who are committed to the pursuit of excellence. Engineers who are challenged and encouraged to create, innovate, and develop technology-based startups.

Like many countries around the world, Brazil resents technological entrepreneurship. Engineers who have been graduating over the past few years resent an entrepreneurial education that develops skills to motivate them to venture into entrepreneurial activities in the field of technology, whether creating companies, or acting as intrapreneurs in large companies or startups. Aware of this challenge, in 2012 the Lorena School of Engineering of the University of São Paulo (USP), Brazil, introduced an Entrepreneurship course in the curriculum of its majors. This course is mandatory for Production Engineering, Physical Engineering and Chemical Engineering, and optional for Environmental Engineering, Biochemical Engineering and Materials Engineering. The course aims to foster the culture of entrepreneurship, develop entrepreneurial competences, and encourage students to create startups.

Training engineers with an entrepreneurial mindset requires revising traditional models of education, and the Entrepreneurship course created at the Lorena School of Engineering has adopted active learning methodologies since its first class. Higher degree of involvement, dynamism and interaction are fundamental characteristics of this type of methodology, as it uses strategies and techniques aimed at engaging students to take on the role of leaders of their learning (Roig & Stoyanova, 2018; Martinez, 2020).

The use of active methodologies has been encouraged by researchers for their importance and effectiveness in education, since the principles employed by these methods enrich pedagogical dynamics. Thus, in the first principle, students become agents of their own learning, that is, they are the center of the teaching-learning process (Marchesi; Coll & Palacios, 2018). In turn, the teacher becomes the facilitating agent, mediating the learning process and instigating students' knowledge. Thus, the second guiding principle of active methodologies is to encourage student autonomy, which provides benefits for their personal and professional lives (Bai; Hew & Huang, 2020).

There are countless active learning methodologies. Those that have been used in the Entrepreneurship course at the Lorena School of Engineering are peer instruction (Nicol & Boyle, 2003), gamification (Dicheva, Dichev, Agre, & Angelova, 2015), project-based learning (Pereira, Barreto & Pazeti, 2017) and flipped classroom (Stöhr; Demazière & Adawi, 2020).

Gamification, one of these approaches, involves participants in problem-solving through gaming principles. It can be applied digitally (through the use of software) or not digitally (such as with board games) (Jantschgi, Scheff &, Erkner-Sacherl, 2020). In general, organizations seek to develop innovative aspects from simulations in contexts that are as close as possible to real life. According to Ramli et al. (2018), the application of experiential learning tools and business simulations in the teaching-learning process enables students to develop skills and competencies that will be required in their professional lives. Gamification principles have been very well explored in entrepreneurial education, because in addition to contributing to learning, they enable students to have new ideas that can yield future ventures (Krajger, Lattacher & Schwarz, 2020).

Invest Game, the central theme of this article, consists of a game created to be applied in the Entrepreneurship courses offered at the Lorena School of Engineering. This course is taught in 15 weekly 100-minute classes. It is led by a professor and a team of 6 mentors, who are undergraduate or graduate students who have knowledge about entrepreneurship from personal experiences on the topic. Students set up teams (referred to as startups) of a maximum of 6 members. Each of the startups must create a business that meets one of the 17 Sustainable Development Goals (SDGs) on the UN Millennium Agenda (United Nations, 2020).

2 Invest Game

Invest Game is a gamified system developed specifically for the Entrepreneurship course of the Lorena School of Engineering, aiming at greater interactivity between all students, as well as enabling learning about startup investments. In addition, it focuses on developing the students' critical analysis competences, creating an environment of healthy competition, and stimulating an improvement in everyone's performance throughout the semester.

Invest Game was inspired by the classic entrepreneurship game show "Shark Tank," a North American show based on the old reality show Dragons' Den (Adalian, 2013), which already has versions in several countries, such as "Shark Tank Brazil." The show features aspiring entrepreneurs who present their business idea to a group of potential investors, called "sharks," who then ask some key questions to better assess the business proposal and decide whether to invest in the company.

Invest Game works based on some of the projects developed in the course, applied in three rounds of investment during the academic semester. The objective of these investment rounds is to enable the use of assessment criteria similar to those used by investors in the real world when making the decision to invest money in new startups.

Each of the three rounds of Invest Game has two stages. The **first stage** consists of feedback for each project developed, delivered through an online form with the criteria to be evaluated using a Likert scale (Likert, 1932). This step is carried out individually by all students, so that everyone knows what the other startups are developing in the course. Students are expected to develop a critical sense, as they will be evaluating startups, including their own. The **second stage** consists of making the investments, which are be made in **U$pins**, a virtual currency created for Invest Game. It has symbolic value, with limits and rules on how it can be used to classify the startups, simulating an investment situation. In this first round of investment, each startup receives 500 U$pins to invest according to the rules defined in Section 2.4. To make the investment, it is necessary that all students from the same startup get together and analyze their individual assessments made in the first stage, as they must make a decision as a team on the amount they will invest in each startup, using a second online form specific to this stage.

The **course mentors** also invest, in parallel with the activities carried out by the students and startups, in each of the investment rounds. They have 500, 500 and 1000 U$pins to invest, respectively, in the 1st, 2nd and 3rd investment rounds, following the same rules as the startups.

After each investment round, a general investment ranking is generated, which consists of the sum of the investment made by the startups and the investment made by the mentors. The result is used as a criterion for granting an amount of U$pins for the next round of investment for the first 5 places, with the additional value granted per placement available in Table 1.

Table1. Grant in U$pins according to the position in the ranking.

Position in the ranking	**Additional Value (in U$pin)**
1st	250
2nd	200
3rd	150
4th	100
5th	50

2.1 First Round

The first stage of the first round of Invest Game consists of posting a video presentation presenting the business model of each of the startups, based on Lean Canvas (Maurya, 2012). This is done through an online platform used by USP. The video must have a maximum duration of three minutes. All students in the class must watch all videos in their class. Then, they must answer an online questionnaire using the Likert scale with the statements presented in Table 2. The scale used was 1 to 5, where 1: strongly disagree and 5: totally agree with each statement. This same scale from 1 to 5 was used in all other questionnaires, based on a Likert scale.

Table 2. Statements of the first round.

The product or service proposed by the startup is highly **innovative/original**, standing out as a pioneer in the industry in which it intends to operate.
The potential for **scalability** (accelerated growth) of the proposed business is high and it has a large market in Brazil.
The proposal fully meets one of the 17 **SDGs** of the UN Millennium Agenda, as established as a fundamental rule of the Entrepreneurship course.
The product or service presented by the startup is a **real consumer need**.
The **pitch** was very well done and left no question about the problem that the product/service intends to solve, as well as the proposed solution that it intends to develop.

2.2 Second Round

In the second round of Invest Game, the Minimum Viable Product (Ries, 2020) is presented. The startups will deliver video pitches of 2 minutes at most, presenting their respective MVPs. From this task, all students in the same class must watch all videos and answer fill out the online feedback and investment form. Table 3 presents the statements contained in the MVP feedback form.

Table 3. Statements of the second round.

The prototype developed has the characteristics of an **MVP**.
The startup has clearly demonstrated that the product delivers **value to the customer.**
The **use of the product** by the customer was well explained in the pitch.
The **basic functionalities** of the product were well clarified in the pitch.
The **pitch** was very well done and left no question about the product it intends to deliver.

2.3 Third Round

The third round of Invest Game consists of "My Startup," which is a booklet containing essential information about the Startup, such as Visual Identity, Team, Target Audience, Business Model, Monetization and Market. "My Startup" is a summary of the Business Plan that is presented by all startups at the end of the semester. The statements contained in the "My Startup" feedback form are shown in Table 4.

Table 4. Statements of the third round.

The **problem** in well-defined and is relevant.
The proposed **solution** really meets the needs of customers.
The proposed **market** is suitable for the defined problem and the proposed solution.
The proposed **indicators** are realistic and feasible.
The "My Startup" enables a perfect understanding of the startup's **business model**.

2.4 Rules

For Invest Game to function, a set of rules was developed seeking the effective participation of students in the game, considering that this can generate a bonus in the course final grade. In addition, the rules are also important as they instruct about the investments made by each startup. The main rules of Invest Game are:

- Each startup can invest up to 30% in its own business in each of the three investment rounds. If the investment exceeds 30%, it will be considered NULL.
- All investment funds must be used in each round by all startups to invest in up to 5 startups, including the their own.
- Each startup can invest a maximum of 50% in a single startup, except their own, in each round of investment.
- The startup will lose 10% of its investment amount for each member who does not watch all the videos and completely fill out the pitch feedback form for the other startups.

2.5 Awards

Invest Game has two types of awards:

- Based on the ranking generated at the end of the semester, which will be obtained by the sum of all the investments of the mentors and students made in the three rounds. Each of the students from startups in first, second and third place will have an increase of 1.0 point; 0.70 points; and 0.50 points in their final course grade, respectively.
- Based on the mentor investment ranking, generated at the end of the three rounds. Each of the students from startups who invested at least 550 U$pins in the startup ranked first in the mentor ranking receives an increase of 0.70 points in their final course grade.

It is worth mentioning that the grades in the course go from 0 (zero) to 10.0 (ten).

3 Application of Invest Game

Invest Game was applied for the first time in 2020 in 4 classes of the Entrepreneurship course, with 2 classes in the first semester and 2 classes in the second semester. The classes had an average of 70 students. For the purposes of presenting the results of the application of Invest Game, only one class will be presented, taught in the first semester of 2020.

The results and analyzes presented in this section refer to the five best evaluated startups by students and mentors (section 3.1). An interesting coincidence is that these were the same startups that received the most investments (section 3.2). Startup 1 developed a used clothing sales platform. Startup 2 developed a platform with the objective of connecting garbage collectors with social organizations that operate in the same area. Startup 3 developed an application to guide the creation of a vegetable garden at home. Startup 4 developed a piezoelectric system to generate energy through the mechanical impact generated by walking and startup 5 developed a device to reduce water waste in public drinking fountains.

Invest Game was applied entirely online through the Google Meet platform, used by the University of São Paulo. The Google Forms tool was used to collect data from the various online questionnaires answered by students in the feedback and investment rounds. The rounds took place between March and June 2020 as detailed in Figure 1.

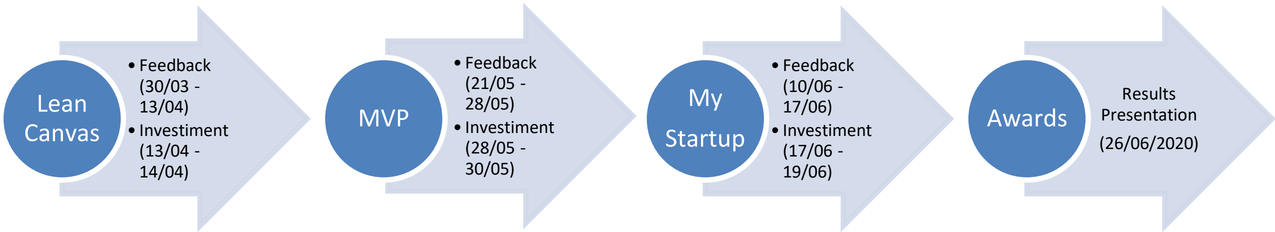


Figure 1. The rounds.

3.1 Stage 1 – Feedback from all students

At the end of each round, online forms were made available for students and mentors to assess the work of each startup in that investment round.

Table 5 presents the averages of each feedback round, for analysis. Only the five startups that had the best performance in the group are presented. This table shows the assessments of all students and mentors in the three investment rounds throughout the semester.

Table 5: Result of the startup assessment feedback carried out by the mentors and students in the 3 rounds.

	1st Round		2nd Round		3rd Round	
Startup	**Students**	**Mentors**	**Students**	**Mentors**	**Students**	**Mentors**
1	4,23	4,13	4,43	4,54	3,95	3,92
2	4,03	3,77	4,21	4,20	4,04	4,05
3	3,95	3,87	3,91	4,10	3,93	3,91
4	4,10	4,77	3,63	3,66	3,65	3,64
5	3,70	3,13	4,24	4,19	4,01	3,98

As can be seen in the results shown in Table 5, the main difference in scores between mentors and students happened in the first feedback round (0.67 in the assessment for Startup 4). In the second round, the maximum difference decreased to 0.19 (see assessment of Startup 3). And in the last round, there was no significant difference.

A possible explanation for the difference of 0.67 in startup 4 in the first round, may be due to the greater expertise of the mentors in relation to the students for the solution presented regarding the generation of piezoelectric energy. It is possible that this theme for being very specific was unknown to some students who were taking the course.

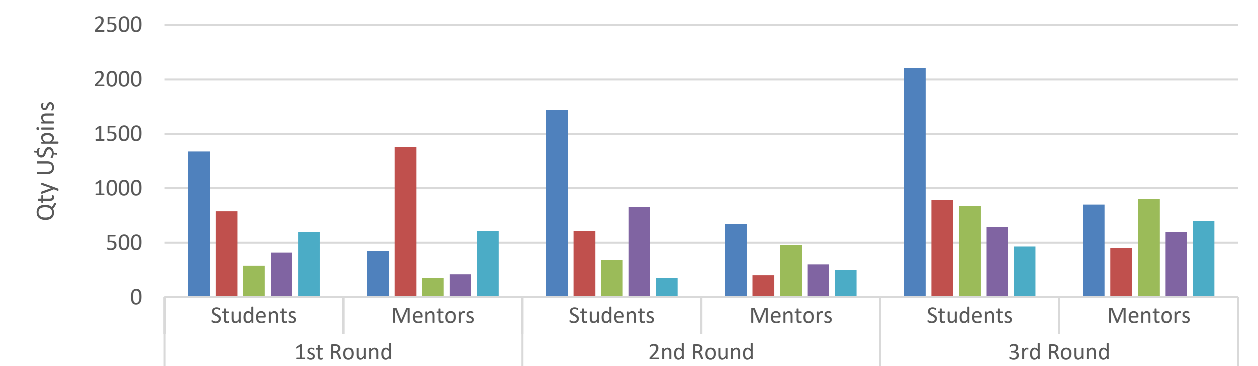
In the second round, there is an increase in mentors' grades. A possible cause could be the fact that the projects were already with a greater degree of maturity because they had already developed the MVP.

The results for the third round, on the other hand, show the smallest differences in grades between students and mentors. A possible explanation for the reduction in the difference between the mentors' and students' assessment score is the greater expertise of the mentors to evaluate startups according to their previous experiences in the area. However, throughout the semester, students learned to improve their assessment competences, so that in the third round, the assessment of students and mentors was similar.

Thus, Invest Game is not only a game that presents and brings Engineering students closer to startup investment rounds, but also increases their assessment competences.

3.2 Stage 2 – Startup Investments

After students completed the feedback form, an investment form was made available for each startup to inform how many U$pins they wished to invest in other startups. Figure 2 shows the investments made by students and mentors in five startups of the first semester of 2020.



	1st Round Students	1st Round Mentors	2nd Round Students	2nd Round Mentors	3rd Round Students	3rd Round Mentors
Startup 1	1339	425	1717	670	2105	850
Startup 4	787,5	1380	607,5	200	891	450
Startup 2	290	175	342	480	835	900
Startup 5	410	210	830	300	643,5	600
Startup 3	600	605	175,5	250	465	700

Startup 1 Startup 4 Startup 2 Startup 5 Startup 3

Figure 2. Section of Investments made by mentors and students in each of the 3 rounds.

There is a discrepancy in the investment in Startup 1 in all rounds. The discrepancy in the 1st and 2nd rounds may be associated with the form of communication used by this startup. The presentation made was much more attractive than that of the other startups. In addition, their business (used clothing sales platform) is something very familiar to investors, in this case students.

Specifically in the 3rd round of investment, it can be assumed that the award given by Invest Game to the startup ranked in second place, influenced investments in Startup 1. This may have happened since startups that invested 550 U$pins in 1st place in the overall ranking of mentors, would receive 0.7 points in the final grade of the course.

3.3 Assessment of Invest Game

After Invest Game was applied in the first and second semesters of 2020, an online form was made available for students to assess the game as a whole.

For this, 5 key performance indicators were defined to verify the assertiveness of the game, using a Likert scale as explained previously in Section 2.1. In addition, a space for comment and suggestions was also made available as an option, for a qualitative analysis.

Concerned with getting answers with no bias, students were only asked to name the Startup of which they were members. Table 6 presents the statements contained in the form:

Table 6 – Invest Game statements analyzed by students according to a Likert scale.

1	Invest Game **added value** to the **Entrepreneurship** course.
2	Invest Game helped to **understand** how **investments in startups** are made.
3	The investment rounds were **relevant** to my **learning process in the course.**
4	The feedback given during the program was important for **the improvement of subsequent projects**.
5	Invest Game **contributed** to the **development of my startup**.

In Figure 3, the averages obtained for each of the 5 statements presented in Table 6 are represented in bars. In this graph, the orange bars refer to the results of the classes of the 1st semester of 2020, and in blue, the results of the classes of the 2nd semester of 2020:

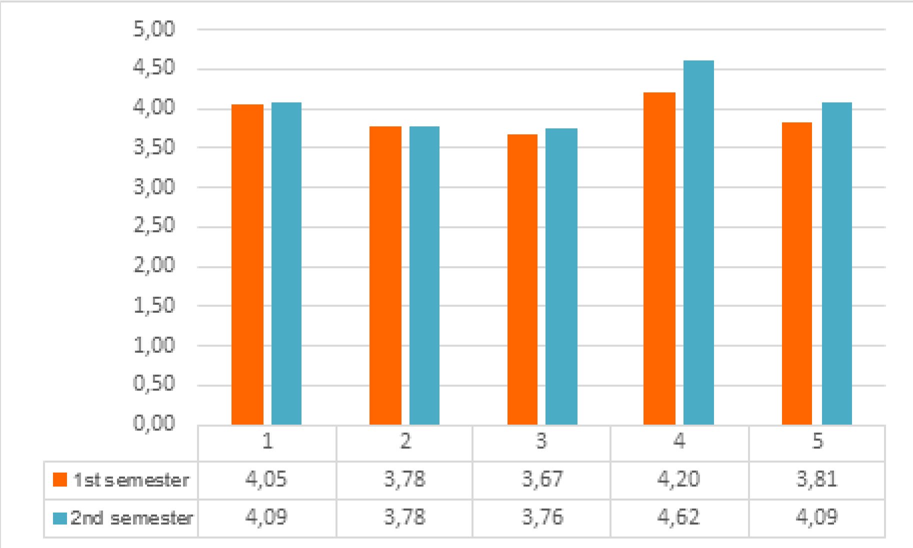


Figure 3: Invest Game assessment averages in 2020.

As can be seen in the graph, Invest Game had average assessments above 3.5. Thus, students more often agreed than disagreed that Invest Game had a positive impact on the course and development of projects. The sample of this research was 80 and 45 students, from the 1st and 2nd semester of 2020, respectively, who answered this questionnaire voluntarily.

This result suggests that the feedbacks given during Invest Game contributed positively to the students, adding value to the course and contributing to the development of the startups.

The responses to statements 2 and 3, despite having averages higher than 3.5, present a specific problem that must be solved in future applications of the game. They indicate that there was not a very clear perception of students in relation to investment in startups and their relevance to the learning process in the course. Thus, as a solution, Invest Game must be better contextualized within the course projects, making reference to the reality of the market, in addition to changing the way of disseminating the results, which were not usually discussed in class.

Below, some of the comments received through the forms:

1. "I think the coolest about the Invest Game was the class - that is, people outside the idea - assessing how the startup was doing, which is very valid. Maybe what can be improved is to better represent a real investment." (Student from the 1st semester).
2. "I didn't like it, because the feedbacks were positive, but when it came to investing, no one did, so we didn't know what we were doing wrong." (Student from the 2nd semester)
3. "Invest Game served to motivate us and to increase the quality of the activities we did." (Student from the 2nd semester)

Like all didactic methodologies, there are positive points and points to be improved. The result of the assessment points out that Invest Game seems to have achieved its objective, since it engaged and motivated students to apply themselves and observe what was being developed by their classmates.

Observing comment 2, the plausible solution is to add a short comment section on the investment form and carrying out a presentation in class clearly comparing the scores and investments of the round, as discussed in this article.

4 Conclusion

The Invest Game was applied to the Entrepreneurship course at the Lorena School of Engineering – USP in 2020. The focus of the game was to develop learning about investments in startups, as well as simulate investment rounds within a university environment. Through the Invest Game, the Entrepreneurship course addressed not only entrepreneurial training, but also knowledge about investments in startups. The surveys carried out at the end of each semester found a good adhesion of the students to the game, which contributed to a better development of projects by the students throughout the semester.

Invest Game proved to be a good initiative. The data collected suggest an increase in the students' learning competences. The game is a good alternative for the practical teaching of investments in startups, which can be applied in other courses and in an adapted way with the purpose of spreading entrepreneurial education.

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Setbacks of the Development of a Concept Inventory for Scrum: Contributions from Item Response Theory

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Abstract

Scrum is the more common framework for agile project management. Agile project management requires frequent feedbacks and delivered items in projects with dynamic requirements and changes. Training learners in Scrum permits building agility in solving problems and teamwork competencies. Measuring training effectiveness is essential to identify students' learning lacks or misconceptions to improve the training outcomes. To assess the development of competences, it is possible to use concept Inventories, which are an essential educational tool to observe students' learning gain between two moments, before and after training. Additionally, the Item Response Theory may be applied to concept inventory items to identify latent characteristics as guessing, difficulty, and discriminant values. Guessing is related to an arbitrary answer to one question and gets the correct answer with common learner knowledge. Difficulty characteristic is related to student knowledge level to one question. Discriminant characteristic considers that learners with high score get accurate answers to the questions. Thus, this work aims to present some of the main setbacks of developing a concept inventory for Scrum, supported by the Item Response Theory. In this way, other researchers may understand how to develop a concept inventory and some of the main obstacles they may have to overcome or avoid. The Item Response Theory offers some indexes and criteria values to each latent characteristic to improve the concept inventory questions. Therefore, this work focuses on the process of conceptualizing, building, applying, and improving a Scrum Concept Inventory in a training situation with engineering students.

Keywords: Scrum, Agile Project Management, Training, Concept Inventory, Item Response Theory.

1 Introduction

Nowadays, engineers face challenges that require a solid foundation in engineering competences such as teamwork, project management, interdisciplinary problem-solving, and oral/written communication (Mesquita et al., 2015). According to Project Management Institute (2013), Project Management is an area of knowledge that mobilizes management concepts, tools, and methods for planning, executing, and closing projects in an efficient way.

The realization of a project varies from determinable and probable to indeterminable and uncertain. A project is considered determinable if characterized by clear, successful procedures and based on similar past projects, such as cars, electrical appliances, or houses. When a project requires a new or innovative design, the people involved can carry out exploratory, collaborative actions and create new solutions, making the project indeterminable and highly uncertain. Examples of people involved who face high uncertainty jobs include software systems engineers, product designers, doctors, teachers, lawyers, and engineers (Project Management Institute & Agile Alliance, 2018).

Traditional predictive approaches applicable to determinable projects attempt to determine the most advanced requirements and control changes through a change request process. In indeterminable projects, it is necessary to explore and carry out actions in short cycles so that the people involved adapt quickly based on evaluation and feedback. An agile approach has dynamic requirements during the project and frequent deliveries of items done. In this approach, Scrum is currently one of the most common projects management frameworks, focusing on managing projects with frequent changes driven by the client's needs and desires. Briefly, according to Sliger (2011), Scrum is an agile method of quickly, iterative and incremental delivery of products that uses frequent feedback and collaborative decision making.

Scrum training allows developing agile collaborative and teamwork competences in solving problems and continually improving products. Adding, training is a process to design, deliver, and implement a learning program for learners about a specific subject or concept. Still, it is necessary to measure the learning before and after the process. According to Lindell et al. (2007), the Concept Inventory (CI) is an instrument to measure learning in education or training situations. Design CI to assess learners' conceptual knowledge or misconceptions as multiple-choice questions (MCQ) to test learners' understanding of concepts. A prominent example, the Force Concept Inventory (FCI), designed by Hestenes et al. (1992), started developing research-based distracter-driven multiple-choice instruments.

This work aims to show details of the process design of a new concept inventory for Scrum and the main obstacles found in the process, identified mainly by analyzing the answers using the Item Response theory to identify latent characteristics - difficulty, discriminant, and guessing.

2 Scrum Concept Inventory

Concept Inventories are a promising tool test for measuring learning gains in specific areas of the curriculum. Tests necessarily measure the type of development in students that a learning gain test also measures. Sands et al. (2018) divided the questions into crucial concepts regarding a subject. Each of them has a correct answer and some incorrect answers or distractions. Identifying misconceptions or mistakes is essential to characterize a student's understanding, becoming a central point to build a valid concept inventory with the right questions and appropriate distractors.

Make the concept inventory's application in two different moments, one moment before the instruction of the concepts, also called pre-test or pre-instruction or pre-training, and another moment after, named post-test, or post-instruction or post-training (Madsen et al., 2017). This allows comparing the two moments' scores to assess the effectiveness of the training performed by an instructor. Concept inventory aims to evaluate the understanding and the implication of concepts differently from the final exams that test various subjects.

Using Scrum Guide designed by Schwaber & Sutherland (2017) as the first source, the research team developed the Scrum Concept Inventory (SCI) with 20 questions in multiple-choice format. Each question had one or more right answers and wrong answers, also known as distractors. The Scrum Guide's choice to create the Scrum concept inventory was motivated because it is the Scrum creators' primary material. The whole community always suggested a continuous improvement Scrum Guide focusing the topic's importance and relevance of Scrum items and events. The SCI has 20 questions divided into five parts: (i) Scrum framework with four questions; (ii) Scrum Team with two questions; (iii) Scrum Team roles with four questions, (iv) Scrum events with seven questions; and (v) Scrum artifacts with three questions. The authors of the study designed all the questions.

Figure 1 describes the process of the design, application, and collection results phases of the Scrum Concept Inventory (SCI) in this study. Before the concept inventory application, the test was designed using the Scrum Guide concepts. The concept inventory application phase was developed in an online training using the Zoom video conference tool. Finally, participants' responses were collected in pre-instruction and post-instruction, in a digital form (Google forms) to posterior analysis.

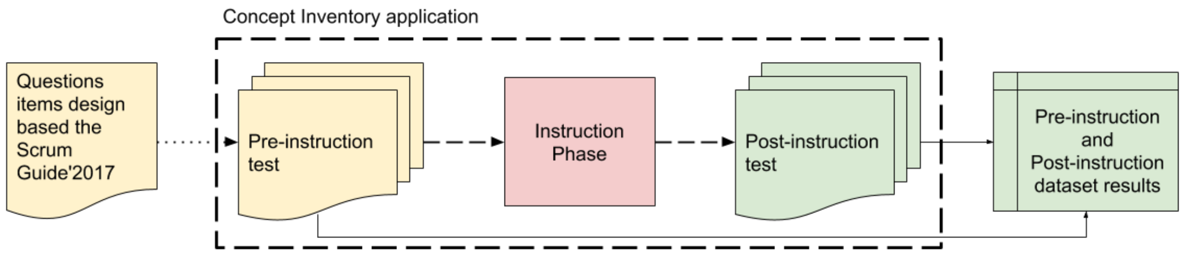

Figure 1. Phases of design, application, and collect results.

The authors created a Scrum Training with an expected time duration between 2.5 and 3 hours to apply the SCI. As commented before, this training's primary material was the Scrum Guide, and participants download it after the training. The Scrum Training used Google solutions like Sheets and Slides to simulate the Scrum events and teamwork communication, respectively. The training theme was about building a city inspired by the Lego4Scrum training (Krivitsky, 2019). The Scrum Training was delivered in four higher education institutes in Brazil and Portugal in 2020, with 51 participants' total. The participants were undergraduate and master's students with different education levels (all with a Bachelor's), ages, gender, and profiles. All participants considered in this study responded to the pre-instruction and post-instruction tests. Their results were collected using a Forms solution, and after the post-instruction, the participants receive their score performance.

3 Item Response Theory basics

A test is a prevalent way to assess learners' learning after the training or teaching, being the obtained score a way to represent the learning result. The Classic Test Theory (CTT) analyses the learners' scores and determines the best or worst results in the same test. According to Rabelo (2013), two learners could have the same score, but their ability levels could be different answering the questions. CTT does not consider the assessed latent features like guessing or question discriminant, for example. The Item Response Theory (IRT) considers the item's test as elements to scores' effects of the assessed' abilities with latent features, not only test score. In IRT, the score result is related to the demonstrated ability level of the assessed.

An IRT model considers that a learner's probability of getting the correct answer is related to his ability level. A high ability should have a high chance, and a low capacity a low likelihood (Sijtsma & Junker, 2006). The IRT permits calculating the learner proficiency or competency according to the test's abilities to compare different learners. The IRT model with three parameters (3PL) is mainly used to estimate the learner's probability in the test's items. The IRT with the 3PL model, as defined in Rabelo (2013):

$$P(X_{ji} = 1 | j) = c_i + \frac{(1 - c_i)}{1 + e^{-Da_i(\theta_j - b_i)}}$$

X_{ji} is the j answer of i item that equals 1 when the learner answer is correct, otherwise 0. The main three parameters of the 3PL model are the a_i, b_i, and c_i. The a_i is the discriminant parameter of the i item that considers that learners with high scores get the correct answers in the easy items. The b_i is the difficult parameter of the i item related to the ability level that considers the necessary learners' ability to get the correct answer to the test item. The c_i represents the learner's guessing feature, which means learners could risk an arbitrary response to the test item and get the correct answer. The θ_j represents the j learner's ability level. The e represents the exponential math function, and D is a scale factor. In IRT, the parameter a_i has a positive value greater than zero. The parameter b_i has values between negative and positive values. The c_i parameter has a variation between zero and one, representing 0% to 100%, respectively.

There are other models with one parameter or two parameters, where difficult and discriminant are the latent characteristics evaluated. In this study, we considered the three parameters model because it had the latent guessing characteristic too.

4 Analysis

With the SCI and the participants' responses, we analyzed the dataset results to compare the performances between two stages, pre-training, and post-training. All the analyses were developed using the R language and some packages like mirt (Chalmers, 2012), ltm (Rizopoulos, 2006), and the R Studio. Before the IRT application, the data from one participant was removed because her/his response was entirely correct in the post-training test. If one participant has a wrong answer to all questions, it would be removed from the dataset. It is similar when there are missing values to any question of the concept inventory. This pre-processing is necessary to avoid bias in the IRT algorithm. Therefore, this work considered the post-training dataset from 50 participants to apply the IRT algorithm.

Figure 2 shows the participants' performance between the two stages, pre-training, and post-training. Two points are outliers of the pre-training results. There are no outliers in the post-training.

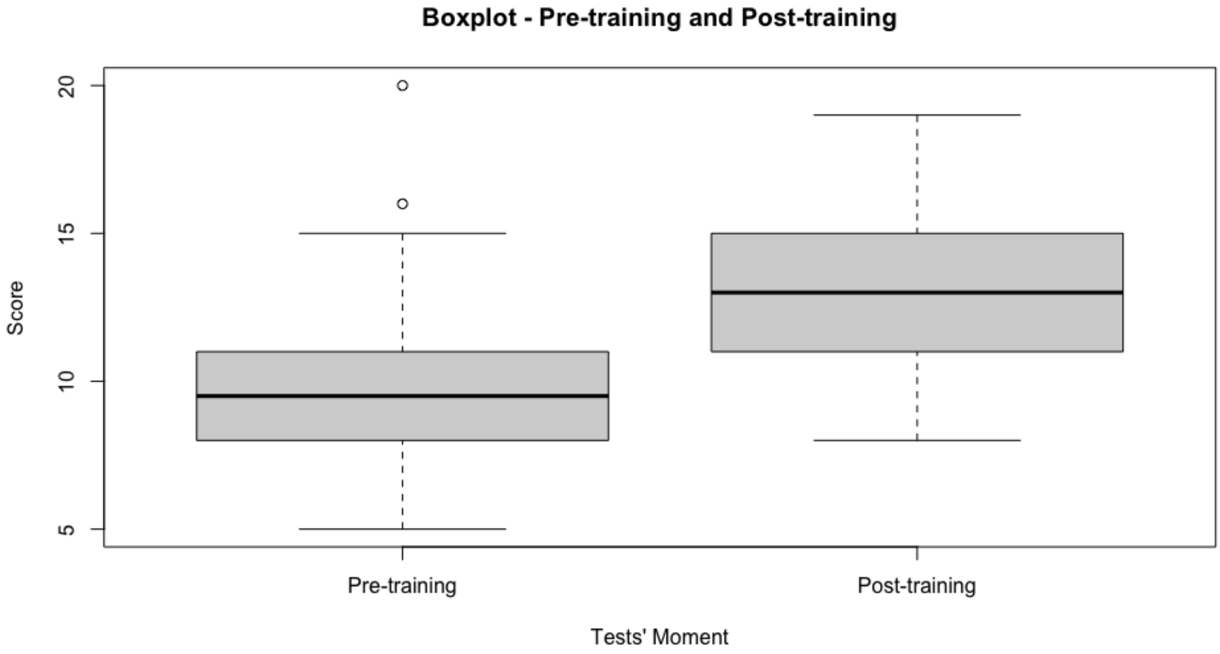

Figure 2. Pre-training and post-training scores' boxplot.

Table 2 shows the descriptive statistics of pre-training and post-training scores for each stage. It was considering the means $\mu_{pre\text{-}training}$ and $\mu_{post\text{-}training}$, was applied paired *t*-student to verify if hypothesis h_0: $\mu_{pre\text{-}training} = \mu_{post\text{-}training}$ is accepted or not. The p-value of paired t-student is least than 0.01, which means that hypothesis h_0 is rejected.

Table 2 Descriptive statistics.

	Min. Score	**Max. Score**	**Median**	**Mean ± Standard Deviation**
Pre-training	5	20	9.5	9.9 ± 3.01
Post-training	8	19	13	13.3 ± 2.48

Table 3 shows the results from the analysis of each SCI item with the mirt package of Chalmers (2012). The dataset is organized by the probability value P(θ) in descending order. The last column shows the probability of getting the correct answer to the SCI questions. According to the IRT-3PL model described before, Q01, Q06, and Q19 have high probability values because all participants responded correctly. On the other hand, questions Q12, Q07, and Q16 had the lowest probability values.

Table 3. IRT Model with three parameters: guessing, difficult, and discriminant, sorted by the probability **P(θ)**.

Position	**Item**	**Guessing**	**Difficult**	**Discrim.**	**P(X_{ji}=1)**	**Position**	**Item**	**Guessing**	**Difficult**	**Discrim.**	**P(X_{ji}=1)**
1	Q01	1.17E-09	-1.819	39.484	1.000	11	Q04	8.33E-08	-0.936	0.905	0.700
2	Q06	7.28E-01	0.437	-88.973	1.000	12	Q14	6.34E-01	0.689	115.177	0.634
3	Q19	8.06E-01	0.663	-45.433	1.000	13	Q17	1.67E-16	-0.315	1.742	0.634
4	Q15	597E-01	-0.038	41.814	0.931	14	Q10	9.96E-17	-0.251	0.993	0.562
5	Q05	1.51E-04	4.549	-0.572	0.931	15	Q03	5.03E-01	0.868	58.400	0.503
6	Q18	5.19E-01	26.157	-0.042	0.880	16	Q08	3.74E-29	0.129	1.236	0.460
7	Q13	8.03E-01	1.437	0.719	0.855	17	Q20	3.36E-01	0.343	131.834	0.336
8	Q11	8.51E-01	1.037	68.393	0.851	18	Q12	8.16E-02	1.391	42.088	0.082
9	Q09	8.01E-01	1.019	156.704	0.801	19	Q07	2.75E-02	1.383	74.179	0.028
10	Q02	1.14E-02	-4.114	0.308	0.782	20	Q16	2.87E-20	1.984	2.338	0.010

Analyzing Table 3 data and the probability associated with each item, Q01 (first position) is the item that requires a lower ability to choose the correct answer. On the other hand, Q16 (last position) is the question that requires a higher ability to choose the correct answer. As defined before, the probability P(θ) is an equation that considers three characteristics, guessing, difficult, and discriminant. All values commented are underlined in Table 3.

Figure 3 shows the ability θ and logistic curve probability P(θ) of each SCI item based on the IRT-3PL model.

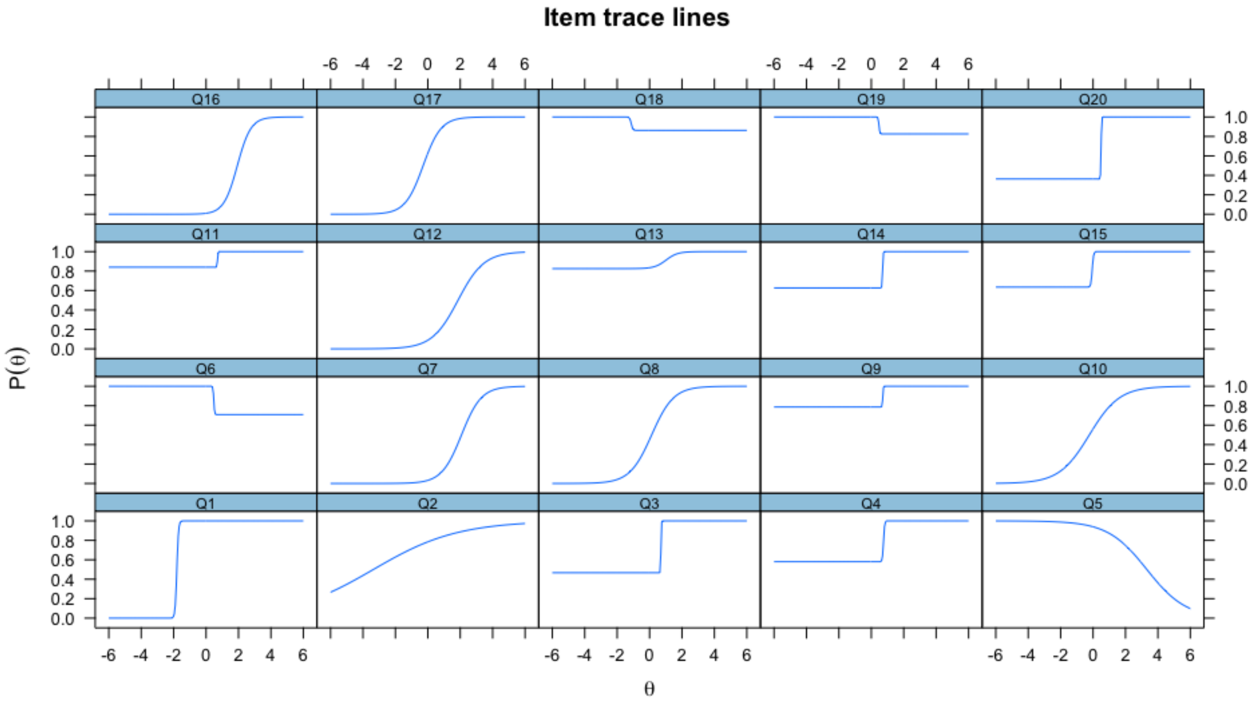

Figure 3. IRT Model with three parameters' curves between ability and probability P.

Concerning the SCI reliable instrument's internal consistency, considering the post-training only, the Cronbach's alpha was evaluated with a 0.545, which means the items are poorly correlated on the test, or there are not enough questions on the test (Taherdoost, 2016). The SCI Cronbach's alpha value should be above 0.7 to be acceptable, but this frequently occurs in initial applications of tests.

Table 4 shows the performance scores for each group separately, considering the pre-test and post-test moments and the number of participants.

Table 4. University performance scores.

Group	**# Participants**	**Pre-test Score** Mean ± Standard Deviation	**Post-test Score** Mean ± Standard Deviation	**Raw Gain**	**Effect-size**
A	14	9.71 ± 2.58	14.07 ± 2.7	4.36	1.65
B	9	9.11 ± 2.93	12 ± 2.5	2.89	1.06
C	19	10.47 ± 3.53	13.11 ± 2.47	2.64	0.87
D	8	9.75 ± 2.71	13.88 ± 1.73	4.13	1.81

The pre-test and post-test scores represent the participants' pre-training and post-training scores' means and standard deviations. The Raw Gain column in Table 4 is the difference between pre-test and post-test mean scores. The Effect-size column is related to a quantitative measure of the experimental effect's magnitude, which means the more significant the effect sizes, the stronger the relationship between two variables.

The effect-size *d* is described by Fritz et al. (2012) as:

$$d_{effectsize} = \frac{raw\_gain}{\sqrt{\frac{\sigma_{pre}^2 + \sigma_{post}^2}{2}}}$$

The goal of the effect size is to provide a measure *d* of the size of the effect from the pre-training and post-training moments. Therefore, the *d* measure determines the efficacy of an educational practice relative to a comparison group. According to McGrath et al. (2015), *d* values were more significant than 0.8, which means more than 79% of participants in the post-training test had learning gains comparing the pre-training test.

5 Discussion

The concept inventory is a helpful tool to measure learning between two moments in a training situation, but the design should discriminate valid questions to participants. The IRT was used in the questions considering three latent characteristics and the participant's scores in training. According to participants' responses to assess the SCI, we were able to verify the quality of each question and a proficiency model of training participants (Figure 4).

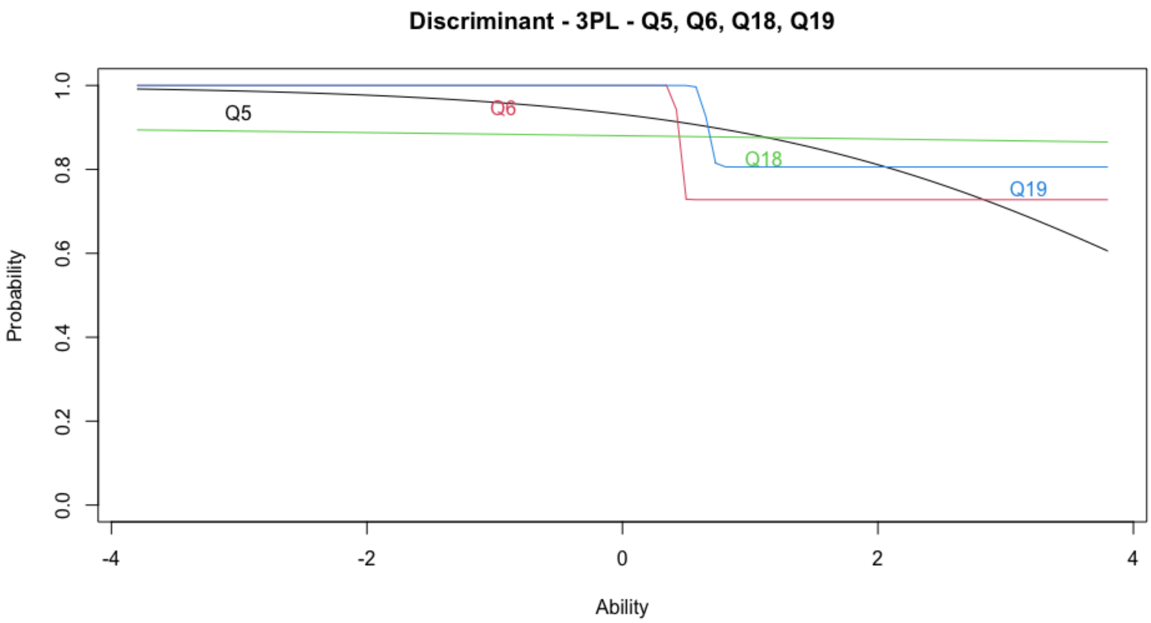

Figure 4. Questions Q5, Q6, Q18, and Q19 curves.

Considering the interpretation of the curves of items Q5, Q6, Q18, and Q19 in details shown in Figure 4, that had negative values, the IRT model indicated textual or misunderstanding problems in the four questions' descriptions. These four items should be discarded or rewritten because their discriminants have negative values, according to Table 3, and the curve's behavior decreases with higher participants' abilities, which is not desirable.

Items Q3, Q4, Q9, Q11, Q13, Q14, Q15, and Q20, have high guessing values and straight-up stair curves. The discriminant's higher values caused the straight-up stair curves. Guessing characteristics with high values indicates that learners with low ability probably choose the correct answer in these questions.

An IRT model's perfect curve occurs when the P(θ) equals 0.5 (representing 50%) for an ability parameter of zero. A curve like the IRT ideal curve is the one for item Q8. Item Q8 has a lower guessing value near to zero that represents the guessing chance to learners with low ability to choose the item's correct answer. The Q8 item difficult is almost zero value that represents the ideal item difficult to the IRT model. The Q8 discrimination value item is related to the curve's slope that is a positive value that causes the tilt direction to be upwards.

Otherwise, a negative discriminant value causes the direction of the slope to be down. According to the Q8 item three values, the P(θ) is equal to 0.46, representing a 46% probability value.

Concerning effect size d, all students' groups in Table 4 had values greater than 0.8, which means more than 79% of participants in the post-training test had learning gains comparing the pre-training test.

6 Conclusion

This study used the Scrum Guide to design the SCI questions, a reference source to Scrum worldwide. We considered that all concepts described in Scrum Guide are essential in the Scrum training.

Madsen et al. (2017) and Lindell et al. (2007) described some methods to assess learning using concept inventories and how they were designed for each topic or area. In Goldman et al. (2008), the Delphi process was used to identify important and difficult concepts about some disciplines in Computer Science, permitting a collection of information and reach consensus within a group of experts. The experts share observations in a structured way, preventing a few panelists from having excessive influence. The experts remain anonymous during the process so that they are influenced by the logic of the arguments rather than other experts' reputations.

As an education questionnaire, SCI must have good values of reliability and validity. As described previously in the Cronbach alpha value, the SCI had low reliability, but this is the first application of concept inventory. According to Kimberlin & Winterstein (2008), validity requires that an instrument is reliable, but an instrument can be reliable without being valid. One type of validity to SCI is to validate its questions content with experts. However, the other strategy chosen by authors was to validate the SCI content with the participants directly using the item response theory because latent trait models have provided an alternative framework for understanding measurement and alternative strategies for judging the quality of a measuring instrument (Kimberlin & Winterstein, 2008).

The next step of this study should be to review the SCI questions and validate their content with a panel of experts. Moreover, it will be necessary to develop new applications of the SCI with other participants to measure its quality using the ITR and the learning gains between pre-training and post-training situations.

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Sustainability-focused international PBL project: Rethinking digital education for individuals of low socioeconomic status

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Abstract

Providing access to education for individuals of lower socio-economic status is a significant way to reduce poverty, as it empowers them to grow as professionals and as individuals. Although there is an increasing sense of urgency to promote these changes, notably motivated by the Sustainable Development Goals (SDGs) set by the UN 2030 Agenda, there are still few successful ways to solve this problem on a large-scale. As digital technology develops and affordability increases, new ways to share quality educational content are created. In an exploratory case study, with a qualitative approach, this paper presents the development of a digital application focused on providing quality educational content directed to vulnerable groups that lack access to formal learning experiences, specifically focused on waste pickers in Brasilia, Brazil. The main data collection methods used to make the decisions through the development process were observation, surveys, and interviews. Within the framework of Problem Based Learning (PBL) an international cross-disciplinary collaboration among different universities, the project, denominated "Mobile Education", involved: (i) the design and implementation of a system consisting of both a web and mobile application; (ii) the research of a viable business model to provide long-term sustainability for the project; (iii) and the creation of a pilot course of financial education for the preliminary target group, i.e., waste pickers from Brasilia, Brazil. Conclusively, the project aims to positively impact social transformation for individuals who work at the Waste Sorting facilities and lack financial knowledge. The Mobile Education project resulted in a functional version of the app (Web and Mobile) as well as the delimitation of a viable business model to keep it providing digital equality in Brazilian education.

Keywords: Digital Education; Problem Based Learning (PBL); Active Learning; Lower socio-economic backgrounds; Computer Engineering; Production Engineering.

1 Introduction

In 2018, the second largest dump in the world, the largest in Latin America, located in Brasilia, Brazil, ended its activities (ISWA, 2019). Consequently, the approximately 2500 waste pickers who depended on recycling waste from the dumpsite, found themselves without a source of income. With the goal of solving this problem, the government created sorting facilities so that waste pickers could still earn income by continuing to contribute to the local recycling chain (Barbosa, 2018; Campos et al., 2018, p. 239). Having provided them a better and prepared place to waste collection, this change represented a relevant transition of working conditions (Campos et al., 2018, p. 226). However, this move of the waste pickers to sorting facilities, came with the side effect of income reduction for the waste pickers. This happened due to the amount of waste available in the sorting facilities being smaller than in the dumpsite (Campos et al., 2018, p. 238; Britze, 2019). In this process, government entities, researchers and waste picker leaderships diagnosed that, in addition to their low incomes, the lack of financial education of this population was a bottleneck for the waste pickers to get their basic needs (Cruvinel et al., 2019).

Aware of this challenging scenario, an international, cross-disciplinary collaboration between Aalborg University (AAU) and University of Brasilia (UnB), the Mobile Education Project (MEP) of the EPIC SDG Challenge (SDGC) initiative, started in 2019 with the goal of providing the support to the waste pickers on their educational gaps through digital learning. Since the conception of the SDGC initiative, students have been working within a Problem Based Learning (PBL) approach, with different teams from both universities working on solving the problem, as a result many premises were validated.

This article presents the development of the most recent MEPs, in which a digital solution is designed and implemented in the context of educating individuals of low socioeconomic status, especially contributing to the Sustainable Development Goals #4, #8, #10 and #17 from the 2030 Agenda (Assembly, 2015). The long-term goal is to increase social mobility, enabling the waste pickers, and in future, other lower socio-economic groups, to seek better and higher paying jobs, in addition to the increases in their competences. Usability, maintainability, and financial viability of the product are prioritized, increasing the long-term sustainability of the solution.

The structure of the article reflects the Problem Based Learning (PBL) framework applied throughout the project, and thus consists of the following chapters: (i) Introduction; (ii) Problem examination and analysis; (iii) Methodology; (iv) Product Development and Implementation; and (v) Conclusion.

2 Problem examination and analysis

The project focus is defined by analysing the specific use case in detail based on the initial premises from the problem. In this section, the problem analysis is comprised of three main subsections: Problem Identification; Problem Examination; and Existing Solutions. Therefore, the problem identification, examination and analysis contain the literature review within a problem based learning approach, in addition to both the results of field research of the problem, and research about existing solutions.

2.1 Problem Identification

The Mobile Education Project focuses on a societal problem: the gaps in the education of waste pickers. The absence of educational access is an issue for vulnerable groups in Brazil, who usually need to enter the workforce early, hampering their learning experiences (Sonia M. Dias, 2011). Specifically, in the case of waste pickers in the Centre-West of Brazil, where Brasilia is located, this scenario is evident by the average rate of illiteracy among adult waste pickers at 17.4% (IPEA, 2016, p. 27). Additionally, 89.2% of the waste pickers have not completed basic education (IPEA, 2016, p. 27) and, therefore, have an extra challenge finding a better job (IPEA, 2016, p. 178). Even though the income they earn from the waste collection is low (Ferraz, C., 2021), especially after the closure of the dumpsite, the way they manage their income can also influence in their financial health. According to the coordinator of one of the waste sorting centres, Cleusimar, interviewed by our team, "it is not uncommon for several waste pickers to run out of money well before the end of the month, even if some waste pickers in a similar situation do not go through the same problem", indicating that, even though their income is low beforehand, the way it is managed has significant impact in their finances.

Therefore, the acquisition of financial education became evident as a central need for the waste pickers. Before providing education that empowers them to change their lives for the future, it is essential that they receive the education necessary to stabilize their current financial situations with better management of their present available resources. Consequently, creating a framework for digital learning content focusing on administration of personal finances is defined as the focus of the Mobile Education project.

2.2 Problem Examination

The determination to solve this complex societal and educational problem through a digital learning method raises two main different challenges: (i) designing and implementing the digital platform, in technical and usability aspects; (ii) deciding the educational and learning approach to be implemented. The challenges related to the technical development of the platform are specifically addressed in the topic 2.3, which deals with existing solutions. Thus, in this problem examination, the focus is the usability aspects of (i) and all aspects of (ii).

In this context, 25 waste pickers and 5 cooperative leaders were interviewed by the research team as part of the investigation process. Throughout the interview process, the goal is to acquire information about their educational backgrounds, their level of technological access, their acquaintance with digital education, their preferred learning methods and approaches, and their greatest difficulties in managing their finances. The information about the waste pickers' educational level revealed that, generally, most of the waste pickers, 65.3%, have not completed elementary school (IPEA, 2016, p. 27) and have difficulties reading, writing, and interpreting.

Subsequently, the importance of adapting the course structure to provide a suitable learning experience is apparent. The interviews indicated that their level of technological access would be appropriate, since most of them, 88%, have phones and internet access. Accordingly, 80% of the group surveyed formed by the waste pickers and their leaders considered a learning mobile application a proper alternative to improve their educational access, since, in their perspective, mobile courses would fit their routines better than courses with scheduled time or in-person.

The decisions of attractive teaching methods and approaches have been pointed by the leaders of the cooperatives as potential points of contention, due to waste pickers' resistance to education in general, occasioned by their past experiences with in-person courses, which were, as described by Campos (2018, p. 235 & p. 237), part of the transition period of the dumpsite closure. Whilst considering this possible issue, the leaders reinforced the importance of using simple communication and contents to keep the waste pickers interest. After the interviews, the requirement for the course is defined with focus on developing the waste pickers' financial management skills through a mobile application with basic financial contents in a simple and didactic way.

2.3 Existing Solutions

Before designing and implementing a solution, research is done into similar products to incorporate the findings into the design and implementation process, ensuring that this project's outcome is singular and novel whilst also gaining insights into potential development paths. Broadening the category of this project into digital learning, a list of most successful applications is analysed, and the main characteristics highlighted (Table 1).

Table 1. Main references of existing solutions.

Name	Kahn Academy	Rise Articulate	Udemy	Kolibri
Description	A course provider focused on mathematics, with recent expansions into science, arts economics etc.	A user-friendly course creation / course completion tool.	A simple course-based learning environment supporting text, images, audio, and video.	A platform used to share already downloaded courses from other platforms between phones whilst offline.
Features	Heavily focused on video for learning. Quizzes to show progress. Gamification of learning. Downloading of videos on their app.	User focused approach, with a great User experience (UX). High quality course creation tools, making it simpler to create engaging courses.	Course creator with a big backlog of other courses. Downloadable content. Support for assignments beyond just quizzes.	High quality offline sharing tool. Open source – can be implemented and modified.
Issues for use case	Downloading videos manually. Unable to create new courses in Kahn, as it is only done by them and their partners.	Resource-demanding and often complex content elements. Rigid integration with mobile applications. High price.	Most courses are behind a paywall, making licensing expensive. Downloading videos manually.	Courses cannot be created on this platform.

Whilst many digital learning platforms are available, none are optimal for solving this use case, highlighting the need for a tailor-made platform to better suit the needs of the waste pickers. The last cycles of the MEP partnership had also produced a functional application based on the model proposed by Mejer et al. (2020)

for financial education issues of waste pickers. Although the platform was successful in many aspects, the focus of it was to be a financial management tool, missing any kind of learning content inside the App.

As a result of this analysis, feature extraction of the different existing platforms is done, gaining an overview of both the core features of a digital learning application and the specialized features that are well suited to the waste pickers' use case. An example of feature extracted is the Kolibri platforms' use of caching, allowing courses to be cloned from one smartphone to another (Kolibri, 2021). The usefulness of this feature becomes apparent based on the research provided in the article by (Britze & Nielsen, 2019) wherein it is established that the courses would only be downloadable whenever the individual user is connected to Wi-Fi. By implementing the same course cloning structure, it could help alleviate this potential roadblock to entry. With these important notes taken from existing solutions, a summary of conclusions from the problem identification and examination is made.

2.4 Subsidiary conclusions

The problem analysis revealed a clear deficit of education tools for both the waste pickers and other groups with lower socioeconomic status. However, beyond this scarcity of educational options, the waste pickers expressed a high willingness to learn, especially via their smartphones. While their perception on the educational mobile application was by a large majority positive, it's fundamental to understand the specific needs for adapting the tool to the waste pickers learning capabilities, by, for example, incorporating text-to-speech and video materials, enabling those with little to no literacy to also benefit from courses (Britze & Nielsen, 2019, p.19; Mejer et al., 2020, p. 43).

Having established these case specific requirements, the examination of existing solutions led to two different inferences. Firstly, it was found that in person classroom-based teaching had proved somewhat ineffective. Secondly, the currently available products in the market do not meet the learning needs of the target group, highlighting the necessity for a tailor-made solution. With these conclusions reached, the methodology for implementing the solutions for this project is defined.

3 Methodology

After establishing key premises about the problem, the methodologies used to solve it are selected and tailored to fit the project. Since the aim of the research is to solve a problem through Problem Based Learning (PBL), the methodologies for implementing PBL in both universities are discussed. Due to the international nature within a larger cross-disciplinary project, project management and teamwork across fields, universities and groups are examined, showcasing the methodology for cooperative PBL based teamwork within larger projects. Therefore, this section is comprised of three main subsections: Problem Based Learning Methodology; Research Methodology; and International Cross-disciplinary Teamwork methodology.

3.1 Problem based learning methodology

Problem Based Learning (PBL) is a student-centred, collaborative, non-traditional approach to education in which students learn about a subject through the experience of solving an open-ended problem as the main responsible in the learning process (Adderly, 1975; Prince & Felder, 2006; Alfaro, Apaza, Luna-Urquizo, & Rivera, 2019). Specifically, in the engineering area, as part of the applied sciences, PBL appears as a strategic mechanism in training students to apply their knowledge in real problems (Cano, López, & Rebollar, 2008; Habash & Suurtamm, 2010; Tran & Nathan, 2010). This approach guides the students to solutions that require extensive use of soft and interdisciplinary skills (Taajamaa, Kirjavainen, Repokari, Sjöman, Utriainen, & Salakoski, 2013). The PBL experience generates a development for students that goes beyond the understanding of hard skills, generating future professionals with good communication and professional skills, both of them continuously tending to be more required in the labour market. (Deshpande & Huang, 2011).

In this context of active learning, a partnership between the University of Brasilia (UnB) and the Aalborg University (AAU), both learning spaces that empowers the PBL approach, emerged. At UnB, the PBL has been part of the strategy since its conception, which aimed to focus education on real problems as a way to form citizens aware of the challenges of the country and the world (Monteiro et al., 2017). Similarly, since the founding of Aalborg University, all programmes are problem Based learning centred (Aalborg University, 2021). By having problem based learning so closely integrated within the university, effectively covering half of the curriculum, international interdisciplinary projects focused on concrete solutions, like the one referred in this article, become possible.

3.2 Research Methodology

This article is made as an Exploratory Case Study with qualitative research approach. Starting from the case of the Mobile Education project as the reference experience, it aims to develop hypotheses and propositions in the context of providing education to people of lower socio-economic status. It also explores the results and, finally, outlines possibilities for a future educational paradigm in the context of international collaboration between universities using PBL, especially in the engineering scenario.

The data collected to establish the instructional design and the platform premises was obtained by interviews focused on qualitative questions, applied to 25 waste pickers in their work facilities and 5 cooperative leaders. The questionnaire consists of questions related to interests, feedback, and some other questions to a set of general profile of a waste picker.

3.3 International cross-disciplinary teamwork methodology

The project is comprised of students from two different universities, in two different countries. In Denmark, two computer engineering students from AAU utilized the scope of creating the mobile education app as their Computer Engineering Bachelors Project (CEBP) and were leading an initiative to make feasible a business model to ensure long-term sustainability for the solution. In Brazil, 3 groups also used the creation of this application as project scopes for the main part of their activities in 3 different PBL based courses of the industrial engineering bachelor of UnB: "Production System Project 1" (PSP 1), "Production System Project 2" (PSP 2), "Production System Project 3" (PSP 3) and "Production System Project 5" (PSP 5), each with a singular focus in the development process.

To certify the success of the expected deliverables related to the mobile application, some risks had to be acknowledged and an action plan should be made to diminish the impact of them. The international cross-disciplinary teamwork was a premise of this project, but it was also the main source of risks related to communication, cultural differences, schedule, and others (Table 2).

Table 2. Tasks from each team.

Risks	Action Plan
Limited dedicated time and schedule from students	Early planning of important deliverables and respective delivery dates
Different project expectations from students and professors	Previous expectation alignment between professors and main stakeholders of each country
Language Barriers between the 2 different countries	Establishing selection criteria for the students participating of the international groups, based on the sufficient knowledge of the selected language for communication between teams
Difficulties in communication between team members due to physical distance	Structured methodology for online communication, reporting and documents sharing
Challenges in the alignment between the teams	Structured methodology for integration between projects and their respective stakeholders.

Having analysed the risks, a tailor-made integration and management methodology for the work involving the different teams is made, focusing on minimizing the risks. To apply this methodology, four steps are considered: (i) Division of Responsibilities; (ii) General Alignments; (iii) Setting Project Owners (POs); (iv) Consolidation of Integration Methodology:

Step (i), Division of Responsibilities: Software design and implementation was a central scope as a way to achieve a Minimal Viable Product (MVP), and pilot educational content must be created to allow a sufficient pilot implementation. Moreover, to ensure the long-term economic sustainability of the project, a business model must be created. Thus, the courses were assigned to each of these necessities (Table 3): CEBP project was defined as responsible for the software design and implementation, PSP2 for researching the problem through interviews and creating pilot educational content, PSP1 for the research of business model viability in Brazil, PSP5 with guaranteeing the quality of all results from PSP2 and PSP3 managing the integration between different teams and stakeholders.

Table 3. Tasks from each team.

Team	Country	Scope
App Developers and Product Owners	Denmark	- Design the app functionalities - Implement and deploy the application - Define and align the expected results from the other teams
PSP 1	Brazil	- Search for improvements and adaptations of the app's Business Model - Checking for possible financial incomes that fits the Business Model
PSP 2	Brazil	- Interview local target market to gather their interests, feedback and general profile - Design the course structure for the app - Detail steps to make a pilot financial course
PSP 3	Brazil	- Manage the schedule and time from the project related demands of professors and teams - Control and supply of deliverables and collected data from each team - Report general status of the project to the teams.
PSP 5	Brazil	- Use of academic research and quality assessment tools to find improvements in the course structure and content created by the PSP 2 team.

Step (ii), General Alignments: Based on the project responsibilities within Table 3, the research team made alignment meetings with each different Brazilian professor, responsible for the courses, and set the goals for each of the future teams working in the projects related to the international collaboration (Figure 1). The Danish team, working in the CEBP, prescinded alignment since the bachelors' project had beforehand the adequate flexibility to fit the MEP needs.

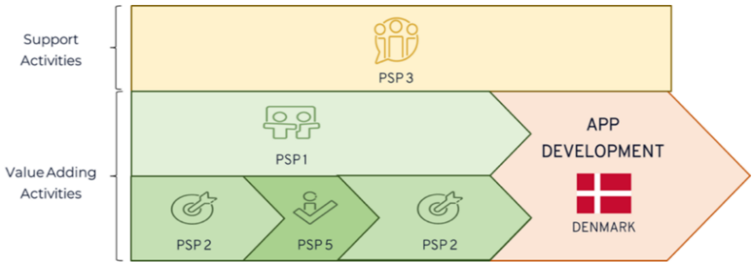

Figure 1. Value chain of the portfolio of projects.

The cooperation and management of deliverables from different teams was a requirement for the project success. The value chain representation was one of the key tools to providing the tailoring of the integration, since, as C.P. Killen & C. Kjaer (2012) described, visual and graphical representation can provide benefits by supporting communication and strategic portfolio decision making.

Step (iii), Setting Project Owners (POs): Besides being responsible for the product design and implementation, the students writing their CEBP from AAU also led the initiative of making a viable business (start-up) based on the digital learning solution. Therefore, they were declared the POs of the entire development.

Step (iv), Consolidation of Integration Methodology: For the transition between the preparation and the practice of the process, an effective integration and management system needed to be developed and communicated (Figure 2).

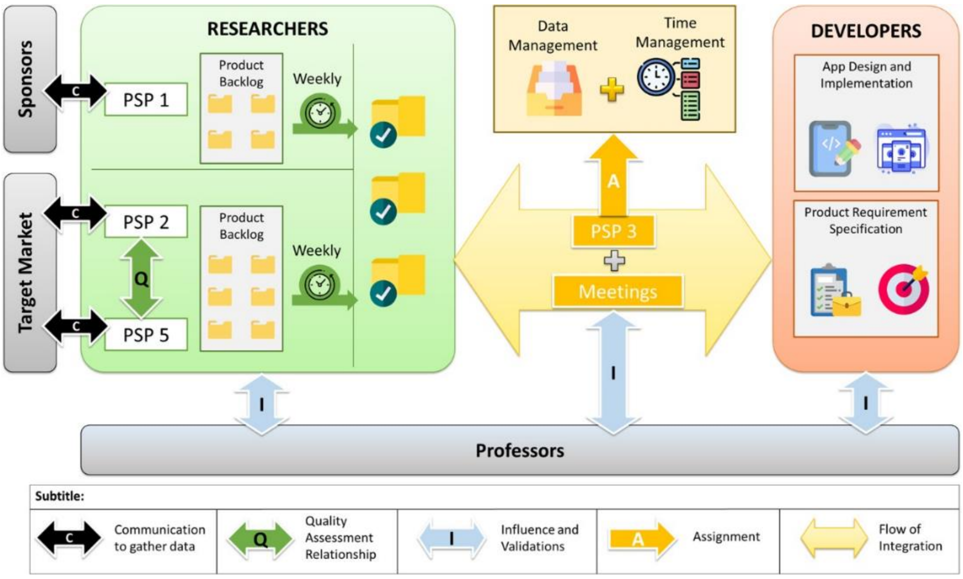

Figure 2. Integration between teams.

Therefore, both the Problem Based Learning Methodology, the Research Methodology and the International Cross-disciplinary Teamwork methodology were defined, and the project, involving different teams, monitors / tutors, product owners, and professors is carried out.

4 Product development and financial strategy

Based on analytical results from user and problem domain research as described in Chapter 2, it is proposed to design and implement a digital learning platform as a distributed web system. The system has two user interfaces – (i) Educado Web, for creating and administering content as well as statistical insights for employers and (ii) Educado Mobile, for smartphone based active learning. During this student project, the ambitions are to develop the Minimal Viable Product (MVP) including both interfaces and connecting them both to a synchronized cloud-based backend handling database and file storage functionality. The general architecture of the system as well as an overview of the applied technologies are systematized (Figure 3).

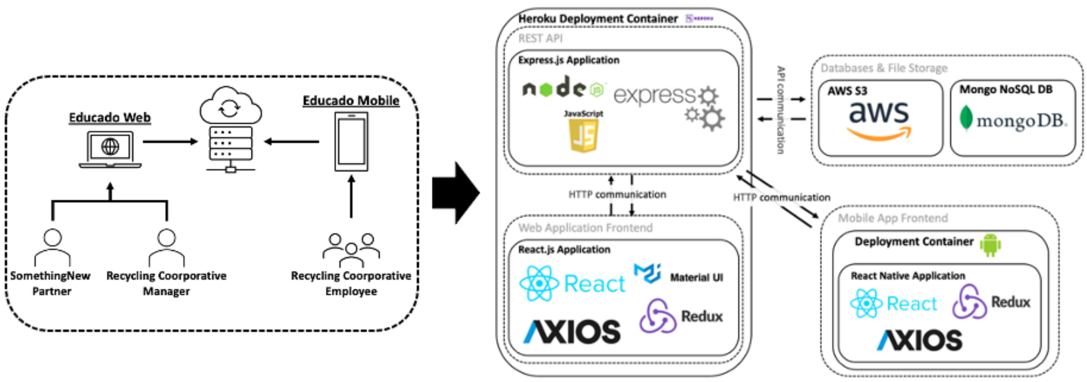

Figure 3. System design.

The system is developed accordingly to engineering principles from Object-Oriented Programming, Structured System Development and Micro-Services software architecture. Design and programmatic decisions are made with prioritization of system maintainability, flexibility, and cost-optimisation. The entire codebase, both backend and frontend sub-systems, consists of JavaScript code and open-source libraries, to keep maintainability costs to a minimum while also creating a flexible framework for further development, as this is important to ensure long-term sustainable use of the product.

4.1 Financial strategy for long-term sustainability as a business

For the solution to achieve long-term sustainable impact, it is necessary to create a viable financial strategy that can support continuous development, project management and maintainability costs. The study driven part of the project is finalized in Q2 of 2021 (Figure 4), whereafter the product ownership is transferred to the engineering start-up company SomethingNew, founded by the AAU participants of the project. Though the project converts to a business-driven development, the cross-disciplinary, user-centred and PBL based frameworks presented in this article are integrated into the project management – and future student projects, are expected to progressively contribute significantly to the project (Figure 4).

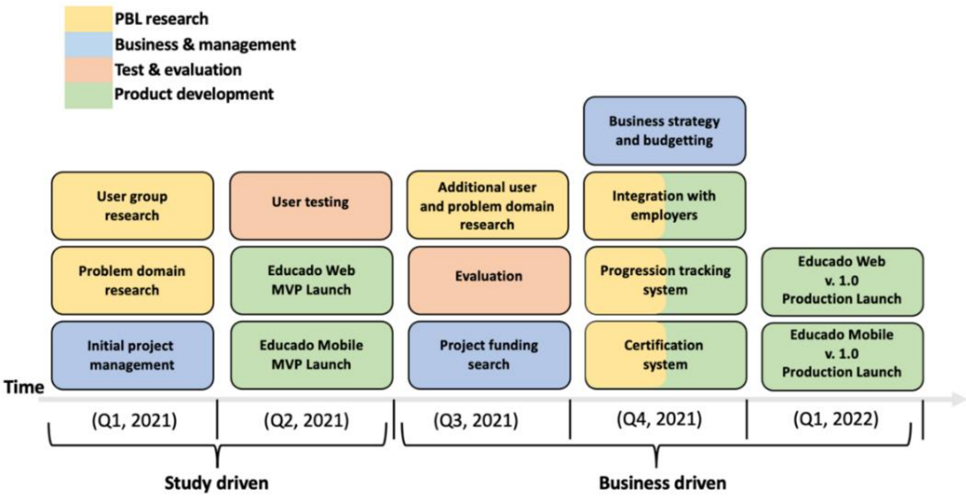

Figure 4. Project planning.

The specific financial strategy of SomethingNew is out of scope of this article, but the expense coverage directly associated with this product is expected to come from both private and public funding. Organisations dedicated to UN's sustainability development goals are expected to support the project through strategic partnerships.

4.2 Course implementation

The creation of an instructional course is accomplished via the learning design methodology, as described by Filatro (2008), which involves four steps: plan, design, execute, measure. This project, carried out by the PSP2 team, is focused on the parts of planning, and designing, which will create the basis for the execution and measuring parts to be carried out in future projects. For the current initiative, a pilot version of the course was developed as a gate between the design step and the future execution step.

The planning step starts by conducting an analysis of the real needs of the users, who, in this case, are the waste pickers. As mentioned in the problem examination, section 2.2, their main educational gap was found to be in financial education, and their basic learning requirements were also defined. Therefore, this section of the article is focused on the following step, which includes the results of the design part.

The course design started with the definition of the teaching sequence, chosen as the following: (a) How to manage your finances and to make your budget (how to plan, register and control the budget), (b) Spending less and saving more (how to stick to the plan, how to avoid making debts, how to save for your future), (c) Investing for the future (where to invest for each goal). Then, aiming at obtaining a problem based learning course, learning situations were developed, which are embodied by a character, who will join the student through the entire course, simulating real-life problems. This strategy not only makes the student closer, by creating identification with the character, but also retains the student during the whole learning process by instigating him/her to figure out how to solve the problems proposed. Finally, for the choice of means and resources, the most important factor is the use of simple words and interspersed procedures with the resources included in the platform, such as short videos, audios segments, simple texts, and clear images.

The design of pilot practical exercises is also a part of the design step and was carried out and integrated in the Educado platform for real world testing with the target group. Therefore, the complete and functional MVP was achieved, as a pilot product for implementation with waste pickers, demonstrating the effectiveness of the MEP international PBL partnership in reaching the established objectives.

5 Conclusion

The platform developed in this project in the context of the Brazil-Denmark partnership matches the waste pickers needs to solve the limitations they face in their learning processes. The Mobile Education app can empower them not only to further evolve their financial lives in their current situation, but also is able to develop new competences to allow them to find other jobs, thus enhancing their conditions for social mobility.

By extrapolating the results of the present work, the future SomethingNew product can create a similar propitious learning environment for different groups in lower socioeconomic situations. Therefore, obtaining a funding model for the philanthropic business initiative that can receive support from various organizations aiming to help different specific groups of people in vulnerability status.

This partnership between Brazil and Denmark evidenced important ways of concrete achievement coming from international cross-disciplinary entrepreneurship in the University context. The Danish team had the computer science skills and the idea of transforming the Mobile Education project in a sustainable business part of SomethingNew, while the Brazilians had closer the business planning and management skills, and closer contact to the waste pickers, a key target group.

As it was effectively applied in this scenario of complexity, involving an international collaboration environment, the methodology for conducting the project proved to be flexible and adaptable for its purposes, elevating the learning potential for the student and creating more value to the stakeholders. Even though the methodology facilitated the job done by the groups involved, there is still a lot of risks related to variable motivation and performance from students, which could eventually become a bottleneck to the whole process if an individual team does not accomplish their assignments, putting at risk the other related projects. The early alignments of expectations and showcase of expected results were vital to the success of the project. Moreover, following the PBL standards, professors and monitors created a free development environment for students, stimulating self-sufficiency for the teams to resolve the problems on their own.

The students reported that the cross-disciplinary approach combined with the interdependency between teams was a key factor of engagement, having provided more motivation than in their previous experiences in the standard PBL methodology. Whilst ratifying the students' perception, professors reported that the methodology applied brought a substantial gain in both the students' attention to quality and their willingness to ask for advice during the semester. The social sustainability-related theme also appeared in the reports as a relevant aspect of the engagement. Both students and professors stated that the high level of interdependence between teams generated some challenges not usually found in the conventional PBL modality, such as managing diverse schedules, communication standards, and types of workflows between different teams. However, they pointed out that their level of learning has grown at a similar rate to the challenge. The authors are aware that there is a balance between on the one hand being motivated through the dependencies among teams, and on the other hand that each group should be able to complete their projects successfully even if other teams do not, therefore each teams' deliverables contribute significantly to the project without compromising other teams in case of potential issues.

The main limitation of this PBL international experience were the restriction due to the pandemic scenario, which prevented face-to-face meetings, adding extra uncertainty to the projects since most data collecting methods relied in interviews and in location observation. Another difficulty experienced was adjusting and fitting the project requirements and schedule with the variable different requirements and schedules of the courses in both universities.

For the next semester of the Mobile Education initiative, the goal is to obtain partnerships with a financial support equal to the running costs and future developments of the platform. Additionally, there is the key aim of utilizing the UnB-AAU partnership to conduct more projects and research, mainly focused on creating new courses in the platform and testing the quality of the application to ensure the users like using it as well as finding value in the educational content provided.

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Adapting to online education through project-based learning in a complex remote zone (Magallanes /Chile)

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Abstract

Faced with the health emergency caused by the SARS-CoV-2 virus, the Chilean government declared a state of catastrophe due to public calamity throughout Chilean territory. The University of Magallanes, since the beginning of the 2020 academic year, has started online classes. Accelerated changes have been motivated the development of theoretical and practical classes in laboratories for both the Construction Engineering faculty and students. Forcing them to adapt to this new form and to face the learning of engineering from their homes. The purpose of this research was to evaluate the learning process carried out during the academic period, as well as the effectiveness of its implementation in a virtual model of the design of the General Construction and Structural Analysis I courses. One of the ways to learn about the student's perception of the implementation of the virtual learning was through a final survey on both subjects, that evaluated the criteria of internet quality, satisfaction with the activity carried out, and the quality of the item. In the General Construction course, the laboratory was evaluated by asking the students to build a scale model of a house. This was carried out through collaborative work in a project which was evaluated by items through photographs uploaded to the cloud. The passing rate of the students was 90.9%. For the Structural Analysis I course, we used the teaching methodology called "Design Thinking". The assignment consists of making models with accessible materials in their home and of which the structural models differ between an inverted catenary and a suspension bridge. The evaluation was through a video with teacher feedback. The students passing rate was 72.7%. The evaluation of the process through the survey was considered positive by the students.

Keywords: Online classes; Construction Engineering; Assessment; Project Based Learning.

1 Introduction

Given the health emergency caused by the SARS-CoV-2 virus, the Economic Commission for Latin America and the Caribbean (ECLAC) indicates that in the field of education, a large part of the measures adopted by the countries of the region in response to the crisis was the suspension of face-to-face classes at all levels. All these have originated the deployment of distance learning modalities, using a variety of formats and platforms (with or without the use of technology)(NU.CEPAL, 2020).

The University of Magallanes started the Virtual Development Unit (UDV) in 2014, which was created because of the need to have an educational option in the field of undergraduate, postgraduate, and continuing education for those located in geographically remote locations. Its purpose is to support the professional development of academic programmes in E-learning and B-learning modalities. Currently, the most widely used tools for the Construction Engineering program are the Moodle© platform (UMAG, 2020b) y Google Drive©.

In 2017, academic staff from the Faculty of Engineering (FI-UMAG) promoted the use of problem-based learning (PBL) in lessons to improve relevant aspects. These are linking with the environment and incorporating real problems which will lead to the comprehensive development and strengthening of soft skills (Lagos et al., 2018). A group of the academic staff was trained on PBL and they indicated that these activities have been used in their classes for some time and on a regular basis, but they were unaware of the concept. The use of PBL dates back to before the pandemic, as it poses a problem and develops problem-solving skills through self-directed learning. (González & del Valle López, 2008)(Barrows, 1986). This methodology is used in the General Construction (GC) course at UMAG. To assess the performance of the future engineer through the exchange of learning files and the use of collaborative work tools the evaluation was done through an E-Portfolio, a folder stored in Virtual Undergraduate or Google Drive© (Tapia Saucedo, 2013). As Paulson and

Paulson (Paulson & Paulson, 1991) said, "the portfolio is a laboratory where students construct the meaning of their accumulated experience". Therefore, academic staff used the e-portfolio as a tool to monitor and evaluate students' achievements (UC Berkeley, 2021) .

Another methodology used is Design Thinking (DT) which focuses on problem solving and applies to any field that requires a creative approach. This allows working in multidisciplinary teams to develop solutions openly and collaboratively way. It stimulates cooperation and creativity and breaks with established ideas to generate new innovative options to address problems or improve situations. Globally, it has become an indispensable method in the innovation process. It is used in companies such as Apple©, General Electric©, and Philips©, among others. Design Thinking is currently widely applied in business schools and innovation centres of universities such as Stanford, Berkeley, and MTI, among many others. (Levine et al., 2016) (Mabogunje et al., 2016).

In addition to spreading the DT methodology beyond engineering disciplines, and involving students in projects with a strong social impact, programmes are increasingly using the potential of the Internet and social media platforms to support open innovation processes on a larger scale (Steinbeck, 2011). This methodology was used in the Structural Analysis I (SA-I) course and the evaluation was through the use of a video. This video should provoke debate in the student when delivering the contents and analysis of what was requested by the academic staff (Jackson et al., 2013). Learners should be able to express knowledge, understanding, and reflection of the content (Campbell et al., 2019).

There are 3.6 million internet landlines in Chile with an annual growth of 5.5%, and 32.8% of these are through optic fiber technology, according to the latest statistics of the Sub-secretariat of Telecommunications (SUBTEL) for the first half of 2020 (SUBTEL, 2020). In the Magallanes region, the quality of internet in mobile and landline services shows deficiencies, such as a gradual decrease in internet speed and availability in certain sectors of Punta Arenas and nearby areas. In the survey of GC and SA-I students, it is highlighted that the main problems are highly variable internet speed and external factors, especially weather conditions. The development of virtual classrooms has made evident the lack of resources of the poor social sectors, (Llerena L. & Sánchez N., 2020). The strategies generated by UMAG were to provide internet accessibility and equipment to students who could not afford them and to be able to develop virtual classes

Under these conditions, both students and academic staff had to adjust to the changes and request technological support. In addition, we should mention that in the Magallanes region we were in an extensive territorial quarantine reaching 114 days. This caused a lack of motivation in the students to reach some soft skills for the development of their practical activities.

This research aims to analyze the teaching-learning adaptation of the lab workshop to the online format in the courses of General Construction (GC) and Structural Analysis I (SA-I). For the analysis, the following activities were carried out: literature review, application of an instrument to measure student’s satisfaction with the virtual classes, and an evaluation. Here, we present the results and conclusions.

2 Methodology

2.1 Subjects characteristics

The Construction Engineering programme is based on the guidelines of the Educational Project for Institutions (PEDI) which focuses on competencies grouped into two categories, generic competencies and specific competencies (S). They establish the depth, scope, and precision of the expected learning. (UMAG, 2014).

Table 1 shows the specific competencies (S) of the 2 courses that will be analysed from the theoretical-practical integration. The "practical" part increases knowledge using laboratory and/or workshops, contextualizing the environment in which the future engineer will be involved (UMAG, 2020a). In the GC subject, students demonstrate general knowledge of constructive processes and codes governing the construction industry. The SA-I course teaches students to determine reactions and to draw internal stress diagrams. They should be able to understand the analysis of hyperstatic structures, apply design and calculation methods.

Table 1. Specific competencies (E) of the courses.

Subjects	CT*	Cód.	Competencies Involved
General Construction (GC)	3	S2 S4	Designing, conducting, and performing experiments as well as analyzing and interpreting their results. Working in multidisciplinary teams.
Structural Analysis I (SA-I)	3	S1 S5	Applying mathematic, scientific, and engineering knowledge Identifying, formulating, and solving engineering problems.

*transferable credits

2.2 Attendees

The students in the target population are in the 2nd and 3rd year of the Construction Engineering Program. Table 2 shows the number of students for each subject, the number of students by gender, by age range, and by passing rates.

Table 2. Number of students for each subject.

Subjects	Number			Age			% Passing Rate
	Total	Men(%)	Women(%)	19-20	21-22	23-24	
General Construction (CG)	11	81.2	18.2	67 %	11 %	22 %	90.9
Structural Analysis I (SA-I)	11	72.7	27.3	7%	50%	43 %	72.7

In addition, it was determined that most students live in the city of Punta Arenas with 93% of the total, while 7% live in Puerto Natales (see Figure 1.). Figure 2 shows the geographical location of the two cities, which are 248 km apart.

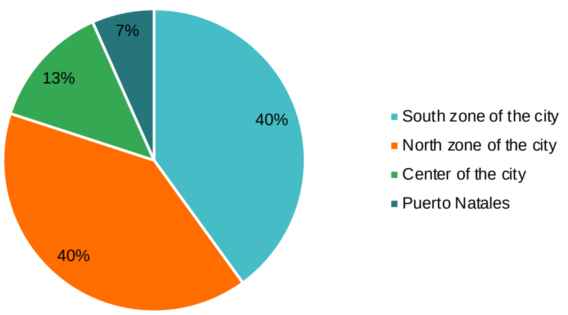

Figure 1. Area of the city of Punta Arenas where the students took their classes.

Figure 2. Location of the Magallanes region. (COMAPA, 2017)

2.3 Student attendance to online lessons

To know the participation of the students in the online lessons, we carried out a survey through a Google© form at the end of the academic year, whose objective was to know the type of internet connection they used and how they developed their online learning. The survey showed that 80% of the students had a landline internet plan at home and they used a laptop. When they lost the connection, 73% of the students answered that they went to someone else's home to solve the problem. In addition, if students were unable to participate in class, 27% “watched the recorded lesson asynchronously” and 53% "got the notes from their classmates for the lessons they had missed".

To determine the reliability of a measurement instrument, we determined the Cronbach's alpha coefficient by using an Excel© spreadsheet for data analysis. The questionnaire contained five questions and five response options, using the Likert scale (1. Never, 2. Occasionally, 3. Sometimes, 4. Frequently, 5. Always) and 13 questions with Likert scale (1. Very Dissatisfied, 2. Dissatisfied, 3. Neither Satisfied/Nor Dissatisfied, 4. Satisfied,

5. Very Satisfied). The alpha coefficient values obtained for the GC course was 0.93 and for the SA-I course it was 0.89 which indicates an excellent internal consistency (Cronbach, 1951) (Frias-Navarro, 2020).

Figure 3. shows the assessment of the main factors that affected the students when they started the online lessons. The survey showed that the main problems were the variable internet speed and some external factors, especially the weather conditions.

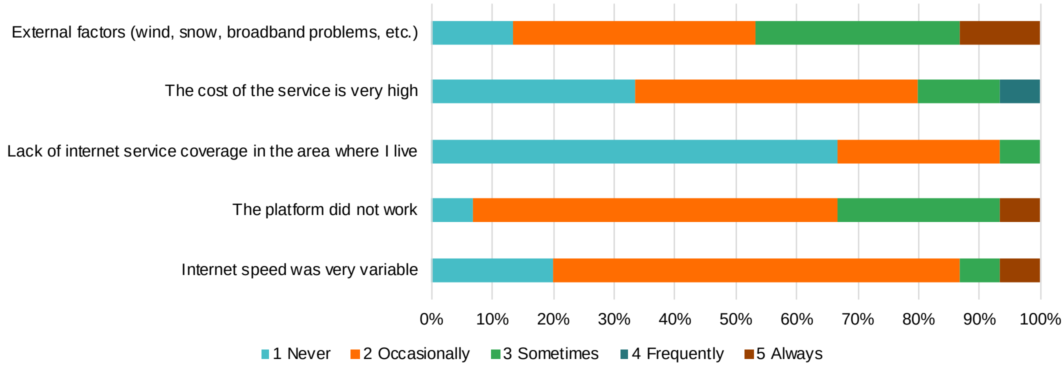

Figure 3. Estimation of the main factors that affected the students.

The second part of the survey determined whether the students recognize any difference in their learning in the online lessons. In this second section, we evaluated whether the laboratory work of the subject was a) useful, b) entertaining, c) could be done in groups, d) helped to consolidate knowledge, and e) was a good complement to the theory. We also asked if the workload for the course was adequate, the help and follow-up were sufficient, and whether the instructions were clear.

Figure 4. shows that 80% of the students rated the course laboratories positively, being a complement to the theory and an entertaining activity. Regarding the tasks to be carried out, 60% of the students answered that the instructions were clear and 55% of them agreed that the workload was adequate. The alternative with the lowest evaluation corresponds to teamwork, which only reached 40%.

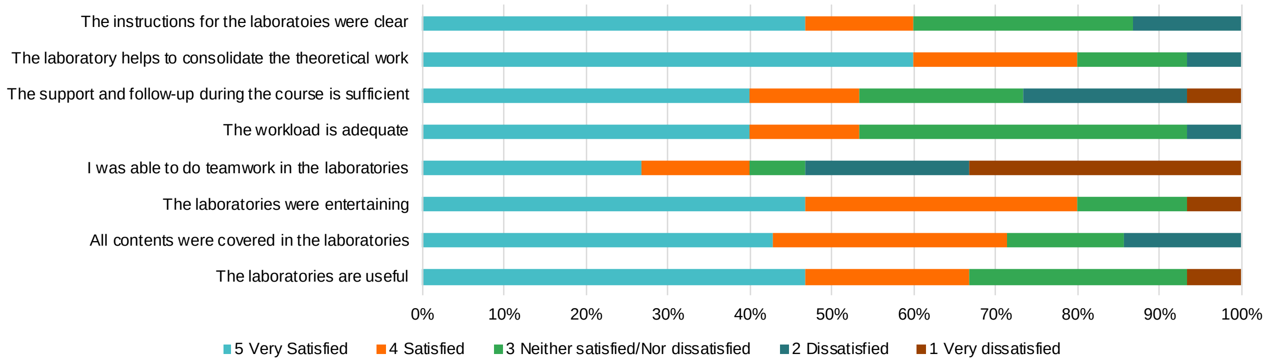

Figure 4. Degree of satisfaction of the practical virtual classes GC and SA-I.

2.4 Satisfaction with the laboratories

For the GC subject, the survey had a third section, which was a rubric asking about satisfaction using a framework that sets out criteria and standards for different levels of performance and describes what performance would look like at each level. The rubric is an element created before starting online lessons because of the pandemic and was used in the same way during this period. This showed that the students in general terms are very satisfied, as can be seen in

Figure 5. The rubric served as a guide for them to prepare their work, providing the main elements to develop. Students expressed 85% satisfaction in this aspect. In addition, the assessment guideline was easy to understand and helped them to improve their work, both aspects reached 72% of satisfaction.

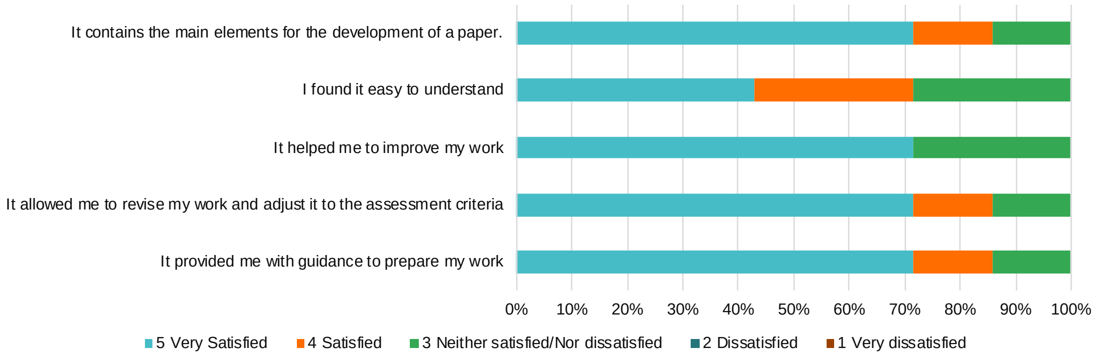

Figure 5. Degree of satisfaction with the rubric of the GC laboratory classes.

2.5 Activity design

Each subject was supported in the virtual classroom of the UMAG Campus – Pregrado Virtual (Moodle©), Google Drive©, and Classroom© where instructions, news, contents, guides, and evaluation were coordinated in a general way. In short, a technological variety of tools have been created for the development of collaborative work. The virtual classes were held via Meet©.

The laboratory of the GC subject is based on the application of a PBL type activity and the online evaluation was carried out through the use of an E-Portfolio. The problem was: "*the housing deficit in the region of Magallanes and Chilean Antarctica, according to the CASEN survey 2017 was 3.601units. (CChC, 2018); to improve this index and increase the employment rate under the pandemic conditions. The state has invested $36 MM for the construction of 1,225 social housing units in 11 lots in the last year (MINVU, 2020). Despite this, the deficit continues. Based on this problem, a construction engineer, owner of a construction company, must design a housing solution for those citizens who cannot access state housing subsidies. For this, they must take into account the following: i) Surface area of the dwelling, ii) Construction systems and types of materials and iii) Project execution time*". *The use of an E-Portfolio is an appropriate tool to consolidate collaborative learning and facilitates academic work. This activity was called* "*Construction of a single-family house*". The purpose was to keep learning resources, feedback, and the students' entry records updated during the semester.

In the subject SA-I, the laboratory is based on the application of an activity using Design Thinking. This activity is the following: "*For the application of this teaching model, the student must answer the following question: What is the difference between an inverted catenary and a suspension bridge? To answer this question, each student must study both structural models, propose the design of two structures, one using the inverted catenary as a model and the other one must correspond to a suspension structure. Both designs must support a load of 1 kg. The models can be made with materials of your choice*". The online assessment was carried out employing a video, in which the student had to edit and explain the difference between the two structural systems and what each of the designed models consists of. Also, they had to explain how it was executed and demonstrate that the models can withstand the requested load. With the results obtained, the students had to draw their own conclusions, which were later discussed with the whole class, guided by the teacher.

3 Experiences and Results

The GC subject was historically conducted in the laboratory and the main competencies are presented in Table 1. The students should understand the fundamental elements of design in order to interpret the results, through teamwork. Figure 6 shows the working diagram of the Problem-Based Learning (PBL), where the didactic strategy used is important and the role of the students consisted of their participation in the process of evaluation and design of their knowledge. In summary: Step 1 - House design: the student presents the project of a single-family house; architectural plan, foundations, and wooden structure; Step 2 - Construction company: the learner organises and plans the functions of the company that will carry out the construction work of the "sketch"; Step 3 - Inspection: the student assistant monitors the work through weekly progress of the "model" and review of the work book (through the use of the portfolio) and Step 4 - Construction of the house model: at the end of the semester the student will deliver the model, by means of a photographic set and defense by Meet©.

We concluded that in the laboratories, the students studied the construction systems every week and presented the progress of their models. They also exchanged the experiences of the work they had done and solved their problems among themselves. The contribution of all this is that it develops and shapes a self-taught culture in the students with respect to their learning, applying the capacity for organization, creativity, and responsibility. In addition, it strengthens the links between the online lessons and the participative work between the students, the assistant, and the teacher. All this led to the development of oral expression, the strengthening of character, and meeting the project's scheduled times.

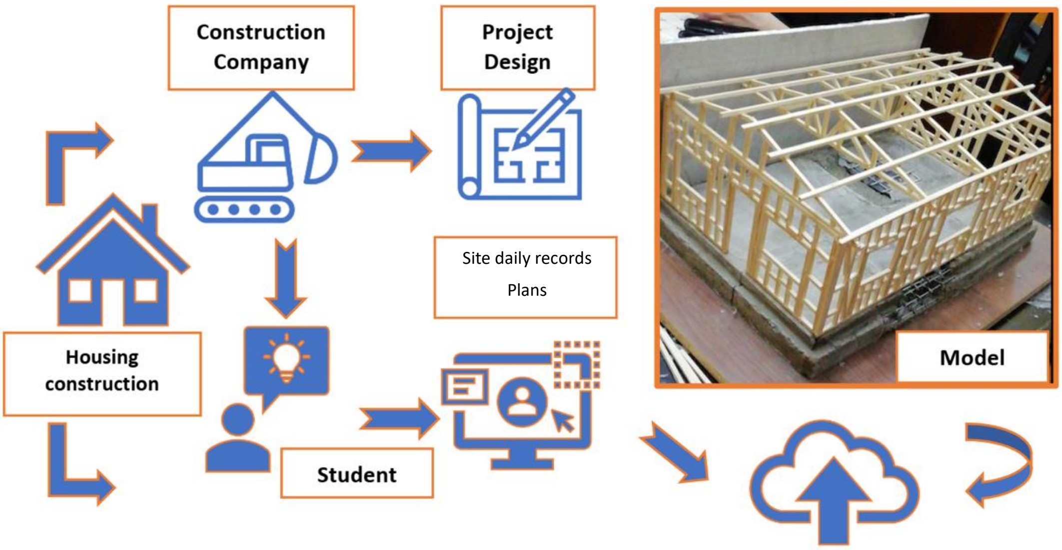

Figure 6. Wooden house construction work–flow.

To produce the models for the SA-I subject, the students followed the following steps: i) Research of the topic, ii) Analysis and calculation of the results, iii) Choice of the materials to be used in the model, and iv) Production of the model.

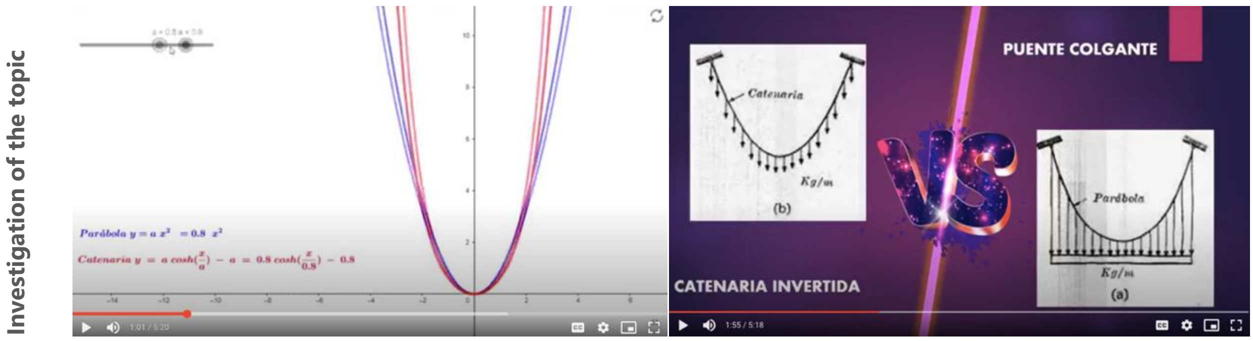

Figure 7. Theory of the catenary v/s parable.

According to the phases of DT, in the first one the student explains the concept of catenary and parabola, and in which type of structures they are used, i.e., empathises and defines the concepts to be used in order to create the project that solves the problem being viable and meaningful. (Villarroel et al., 2017) (see Figure 7).

Analysis and materials.

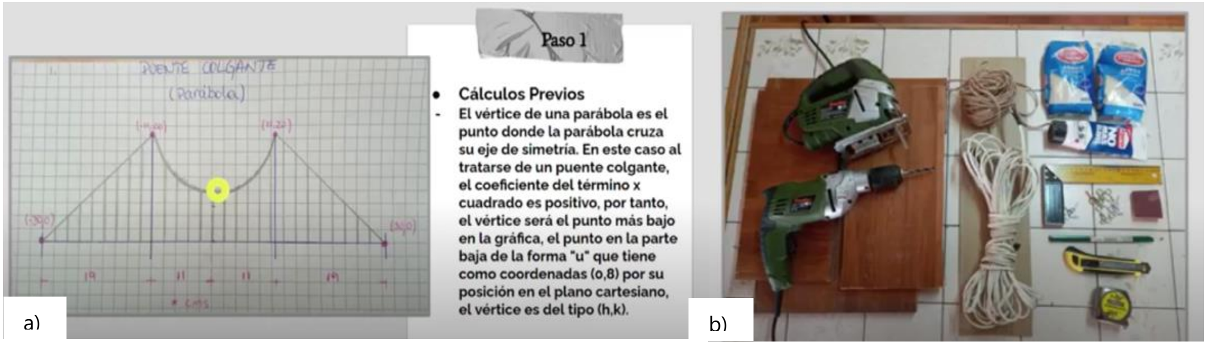

Figure 8. a) Calculation of a suspension bridge, by means of the parable and b) Materials for the elaboration of the model.

When carrying out the analysis and later the calculation (see Figure 8. a) the students executed their design firstly in sketches that served as a guide for the construction and/or elaboration of the model. In the Figure 8 b) the students could choose the materials for the model, prioritizing the use of disused-recycled materials found at home. In this phase, students developed the model and tested the prototypes with 1 kg (Villarroel et al., 2017).

Models

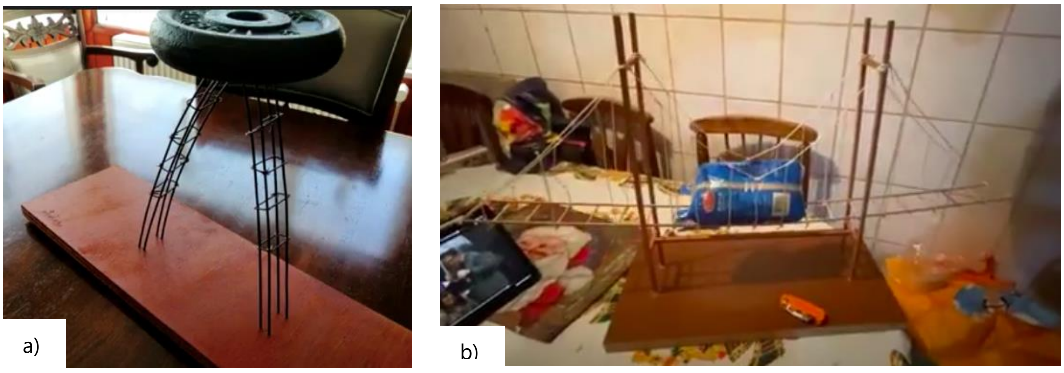

Figure 9.a) Arch created by using the catenary and b) Suspension bridge, using the parable.

Each student built 2 models representing the concept catenary structure and suspension bridge, respectively. In phase 3 of the DT method, the solution is evaluated, in this case, it is 100% technical by fulfilling the resistance with 1 kg (eg: sugar, flour, etc.) Figure 9.a)

At the end of the activity, all students presented their work to the class, generating a discussion of the observations and results obtained individually. All of this was guided by the teacher responsible for the subject.

In summary, this research helped us determine the existence of gaps such as access to connectivity, digital skills (teacher-students), and skills in teaching methodologies. Added to this is the resilience of students and teachers who now need more time to comply with scheduled activities. Based on this, future classes will be a mixture of face-to-face laboratories and online theoretical classes. We will have to work and adapt to learning experiences through technology.

4 Conclusion

This research is summarized in two parts, the adaptation of the laboratory to online lessons throughout the 2020 academic year and the perception of the students using a survey.

Regarding the laboratories, the students considered that they are a complement to the theory and an entertaining activity. Despite having a variable speed internet connection, some of the students indicated that they "watched the videos later" and some that they "shared their notes with their classmates".

The perception of the faculty is also important as they had to redesign the practical experiences and adapt them to the online format. In addition, the autonomy in their learning process often did not happen due to the lack of motivation of the students at the beginning of the pandemic and the switch to distance learning. But despite that, the students managed to develop their organizational skills, creativity, and responsibility in fulfilling the objectives set in the different activities. They also had to deal with another problem which was the access to the materials to make the models, since the local shops were closed due to their lock down (over 114 days), which meant that they had to use recycled materials found at home.

Concerning the teaching methodologies used in the GC/PBL and SA-I/DT subjects, both were implemented even though they were based on collaborative work and that the students worked most of the time from their homes and met in the virtual classroom once a week. They managed to understand and relate the concepts. And they developed greater autonomy in their learning process.

Finally, this research focused on the transformation of the teaching-learning processes from face-to face to the online format. Despite the problems detected by both students and faculty, considering the emergency caused by the COVID-19 pandemic, the results of the process experienced are positive.

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Development of Capstone Integrative Projects as a tool for learning Design and Process Control in Chemical Engineering

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Abstract

In 2016, the Faculty of Chemical Engineering of the Universidad Pontificia Bolivariana implemented a curricular transformation that includes integration between the Process Design, Process Control, and Process Engineering Laboratory courses through an active learning experience based on projects. It is important that the training of chemical engineers is consistent with this integration, bringing them closer to the reality of professional practice in process development. While creating learning experiences, in which students are confronted with challenging questions, construct their arguments, exchange opinions, accept ideas and conclude based on evidence and reasoning. The capstone projects were developed in randomly selected groups to develop a basic engineering proposal for an industrial process of local or national interest. With the development of these projects, the aim is to develop competencies in the design of the chemical engineer, while fostering an environment for autonomous work and critical thinking, so that these three courses converge harmoniously, and promoting learning supported by computational tools. It was conducted an opinion query and a focus group with professors, students, graduates, employers, and administrators of chemical engineering to analyze the relevance of the capstone project. Between 2016 and 2020, more than 43 processes related to sectors comprising: petrochemicals, bioprocesses, environmental, energy generation, among others, were evaluated with students, evidencing a significant improvement in the skills defined by the Faculty in the graduation profile. 94% of the graduates of the program in that period recognize that the capstone project as an integrator of design and process control contributes positively to the professional development of the chemical engineer. In this work, we present the lessons learned in the development of capstone integrative projects as a tool for learning design and process control in chemical engineering faculty and improve the student outcomes to produce solutions applying engineering in context.

Keywords: Learning Experience; Chemical Engineering; Process Control; Process Design; Integrative Projects; Capstone.

1 Introduction

Engineering education in the 21st century requires the students get prepared to face the demands of complex and dynamic work environments, therefore, the student needs to be involved in an experience that comprises complexity, innovation, and application of knowledge in a chemical engineering curriculum (Wolff, et al., 2018). According to Hoffman (2014), an engineering capstone course integrates the skills and competencies that students have learned in their engineering program and should provide a simulated "real world" end-to-end learning experience. The student applies the knowledge of courses such as transport phenomena, thermodynamics, kinetics among others in a capstone project of engineering design and economics whose development takes place during the last year of the degree (Voronov et al., 2017).

The Faculty of Chemical Engineering at Universidad Pontificia Bolivariana (UPB) implemented in 2016 a curricular transformation that included integration between the Process Design, Process Control, and Process Engineering Laboratory courses through a final degree capstone project in which the students propose basic engineering alternatives, solve material and energy balances, evaluate the dynamics of the process. Therefore, students select instrumentation, propose a feedback control strategy, and approach the tuning or self-tuning of control loops. A project-based learning methodology was implemented to develop design competencies.

Several experts highlight the importance of creating these learning experiences, in which students face challenging questions, construct their arguments, exchange opinions, accept ideas and conclude based on evidence and reasoning (Bain, 2014) and point out that the capstone project effectively contributes with learning outcomes related to written communication, presentations and technical reports (Muryanto et al., 2017).

Various authors show the development of a capstone project with the application to a laboratory or Process Control course, i.e., the struvite crystallization process in the laboratory (Muryanto et al., 2017) or the case study of a binary distillation column that involves the design, instrumentation, simulation, and control (Ghossein et. al., 2017), however, the capstone project carried out in the Faculty of Chemical Engineering includes the integration of three courses, previously indicated, and the design and control of processes are applied to the complete plant and not to a single unit operation.

The integration with the Process Control course has allowed a better understanding of the concepts seen in this course, as the student carries out simulations, exchanges opinions, plays with variables, etc. which motivates them to work on different topics and concepts related to Process Control and in this way makes use of motivational active learning (Rodríguez, et al., 2019).

With the development of the capstone project, skills are acquired that favor active learning and encourage metacognition (Ambrose et al., 2017), while allowing the assessment of students' ability to perform as a team, as recommended by ABET and CDIO in their learning outcomes for the training of engineers (Spurlin, et al., 2008).

2 Methodology

The general methodology that is proposed in this work mainly comprises the implementation of project-based learning for the training of chemical engineers, through the integration of design and process control courses in the development of a final-degree capstone project, in which students propose basic engineering alternatives for a process of interest to the country, or strategic areas for sustainable development such as agribusiness, biotechnology, green chemistry, new materials, among others.

2.1 Development of the Capstone Integrative Project

Students are organized into groups of approximately four members at random and are assigned a problem situation or context to develop the capstone design projects. Generally, the preferred raw material or the production route is mentioned, and an instruction guide is sent with the content of the written progress reports that they must present periodically during the development of the courses.

Students develop an integrated design experience, as shown in Figure 1, which begins with the definition of plant capacity, based on market studies using primary and secondary sources. Therefore, they elaborate a detailed review of technical and scientific literature to give conceptual support to the project; finally, they propose conceptual alternatives. Simultaneously, students prepare an analysis in the form of a baseline to evaluate aspects related to the project that include environmental, social, technical-legal variables.

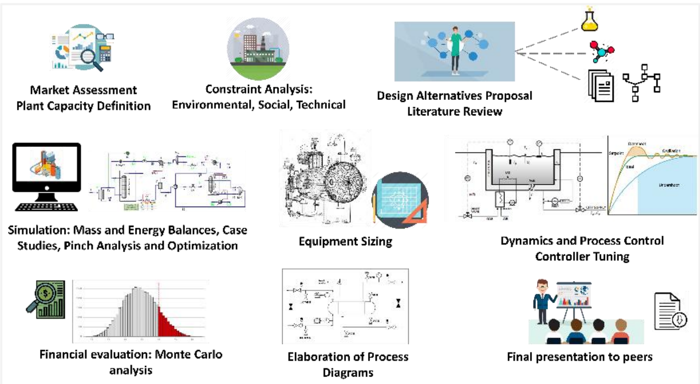

Figure 1. Elements that include the experience of integration, design, and control of processes for the development of the capstone project.

The material and energy balances are proposed, and the process is simulated following a hierarchical level design methodology, starting with the reaction zone, the separation zone, and energy integration using the

Pinch method. The process equipment is dimensioned based on mathematical models and heuristic rules, and the optimization of the operational conditions supported by the Aspen Hysys software is proposed.

In the Process Control course, students use MS Excel to model steady-state processes and find the operating points of the control. Using Matlab, practices were developed that allow the student to evaluate the stability, controllability, and observability of the processes. Integrating different tools such as Simulink and dynamic Hysys, students evaluate the dynamic response of simple processes in a transient state to propose feedback control strategies. Finally, practices are carried out using the Loop Pro tool. The students experience a plant control room environment as a training alternative to achieve controller tuning (Ricardez-Sandoval, 2009).

After advancing in basic engineering, a proposal for feedback control loops for at least one reactor and one separation equipment is prepared. The block and process diagrams and instruments are proposed based on chemical engineering standards, as well as evidence on the selection of sensor/transmitter elements, indicating their essential characteristics and accessories according to catalogs; the actions in failure of the valves used as final control elements; the types of controllers to be used in each control loop; and the actions of the controllers to be used in each control loop.

After the basic engineering preparation, the students carry out the financial evaluation of the process. Monte Carlo simulations are used to evaluate different scenarios and thereby estimate the Net Present Value (NPV) and the Return of Investment (ROI) to infer the profitability of the proposed design.

Finally, the students prepare a 15-minute oral presentation before at least one external evaluator who acts as an industrial peer, the course professors, and assistants from the Faculty of Chemical Engineering. Feedback and summative evaluation are given. Aspects that allow assessing the quality of the capstone project on a Likert scale from 0 to 5 include:

- Definition of the plant capacity according to basic market studies
- Description of kinetic models and design assumptions
- Evidence of the complete simulation (Mass and Energy Balances)
- Evidence of case studies or process optimization
- Sizing of process equipment
- Estimation of costs (NPV, ROI)
- Satisfactory process diagrams (Blocks, Processes Flow Diagram)
- Selection of sensor/transmitter elements for process control
- Evidence of the failure actions of the valves used as final control elements
- Evidence of the types of controllers to be used in each control loop
- Evidence of the actions of the controllers to be used in each control loop
- Management of the time designated for the oral presentation

2.2 Evaluation of the design-control integration proposal for the development of capstone projects

The external view of graduates of the program who participate in industrial activities has served as a learning evaluation tool and feedback in the orientation of these courses. For this reason, an opinion query was first proposed of the graduates of the program with less than five years of professional practice to assess their perception of the relevance of the capstone design experience in their training process. Second, a focus group was held with five graduates with high professional trajectory, advanced training, and experience in the design area, as shown in Table 1, to evaluate the quality of the capstone project and the value it delivers to newly graduated professionals in chemical engineering.

Table 1. Profiles and roles of the graduates participating in the focus group to assess the capstone project of process design and control.

Participant	Profile description	Background and role	Expectations according to role
Graduate 1	• Holistic vision of the profession. • Experience in academic administration. • Industrial experience in research, innovation, and product development. • Representativeness in professional associations.	• 30 years of professional practice. • Master's studies. • Professional practice in at least two different countries.	• Provision of an integrative and complex look. • Issuance of judgments articulated with national and international professional needs detected through professional associations.
Graduate 2	• Experience in innovation management and product development in the chemical industry. • Disruptive thinking. • Professional development in chemical and manufacturing processes.	• 20 years of industrial experience. • 5 years of experience in product development and innovation management positions. • Master's studies in innovation.	• Critical look from the disruption. • Issuance of judgments regarding sustainability and the characteristics of the final product.
Graduate 3	• Experience in innovation management and process development in the chemical industry. • International academic experience. • Management of multidisciplinary design teams. • Deep knowledge of the fundamentals of the profession.	• 15 years of industrial experience in process design. • 5 years of experience in positions of management of innovation, development, and design of chemical processes. • Doctoral studies in chemical engineering or process engineering. • Experience in accompanying projects at the master's or doctoral level in chemical engineering.	• Critical look from the foundations of the profession and the design of chemical processes. • Supply of contrasts with capstone experiences developed in other countries. • Articulation with other levels of training.
Graduate 4	• Experience as an employer of recently graduated professionals. • Experience in new business development in the chemical industry. • Deep knowledge of the international chemical products market.	• 20 years of industrial experience. • 5 years of experience in positions associated with the management of marketing and detection of new businesses in the chemical industry. • Master's studies in administration or related.	• Critical look from the reality of the international market and the chemical business. • Feedback in the context of the performance of newly hired graduates.
Graduate 5	• Experience as an employer of professionals. • Experience in new business and product development in the chemical industry. • Experience as a mentor and companion of new professionals.	• 10 years of industrial experience. • 5 years of experience in positions associated with the detection of new businesses in the chemical industry and the management of high-performance teams in multinational companies. • Master's studies in engineering or related.	• Critical view from the management of high-performance teams and the mentoring of recently graduated professionals. • Contributions for closing university-company gaps. • Critical look from project management.

3 Results

3.1 Innovation implementation process

With the development of the capstone project, skills are acquired that favor active learning and encourage metacognition (Ambrose & Al., 2017) while allowing the evaluation of students' ability to perform as a team, as recommended by ABET and CDIO in their learning outcomes for the training of engineers (Spurlin, Rajala, Lavelle, & Felder, 2008). Additionally, external evaluation by engineers belonging to the industry is incorporated, generating closer feedback of the professional practice, which has allowed the implementation of improvement actions in the approach, the contents, and the teaching practice in the courses.

The capstone project statement is open and seeks to approach the authentic tasks of an engineer in the context of the profession. Therefore, it is pertinent to confront students with relevant questions, construct their arguments, exchange ideas, accept ideas and conclude based on evidence and reasoning (Bain, 2014). Aspects such as the reaction route, the separation strategy, and the basic control loops must be proposed and evaluated by the students; where they learn to make decisions and integrate prior knowledge. According to several experts (Ambrose & Al., 2017), this encourages metacognition, understood as a process of reflecting and directing one's thinking.

By using computational tools in the courses, it was possible to strengthen the research competence, since the students must carry out a bibliographic search, categorize the technical information and thus propose alternatives in the synthesis of the processes, following a methodology of hierarchical levels. It was noticed that students learn to select information to complete the degrees of freedom and autonomously solve the mass and energy balances for the processes. In contrast, a macro was programmed in MS Excel that allows solving non-linear systems of equations using homotopic numerical methods.

Active learning, supported by software, has been achieved, which converges in courses such as the Process Engineering Laboratory, where the student faces uncertainty, decision-making, and asks "what if?" to whole plant dynamics, to build meaningful learning of industrial process design and control (Guo et al., 2020).

The use of computational tools allows students to accelerate the method of analysis of the processes, either by carrying out case studies in a steady state to parametrically optimize the processes and characterize the dynamics of the processes in the transient state to propose a feedback control strategy. By integrating different tools such as Simulink and dynamic HYSYS simulation, the students have even approached the estimation of tuning parameters of the controllers, quickly contrasting different methods for this purpose.

To become self-directed learners, students must learn to assess the demands of the project, as well as their knowledge and skills; also plan their strategy, monitor their progress, and adjust their strategies in the working group as necessary (Ambrose & Al., 2017; Bain, 2014).

The capstone project is not intended for the student to accumulate knowledge but to use it in problem-solving. With the assistance of computational methods in the design or process control courses, a flipped classroom experience is generated, which has the potential to improve the quality of engineering education by providing opportunities for teachers to implement active learning strategies during the classroom. class time (Jamieson et al., 2015).

3.2 Evidence obtained from the capstone projects

The deliverables of the project are carried out gradually according to the level of detail so that the teachers of the design and control courses can monitor the conceptual progress. Additionally, evidence suggests that the benefits of these practical exercises accumulate gradually through a learning curve (Ambrose & al., 2017).

The deliverables are presented in the format of an article. Additionally, it is carried out a formative assessment of the argumentation and synthesis capacity. This presupposes a good learning experience for students, a formative, periodic evaluation process is necessary allowing them to fulfill a higher-order activity. Some examples of the evidence showing the results of the capstone projects are shown in Figures 2 and 3.

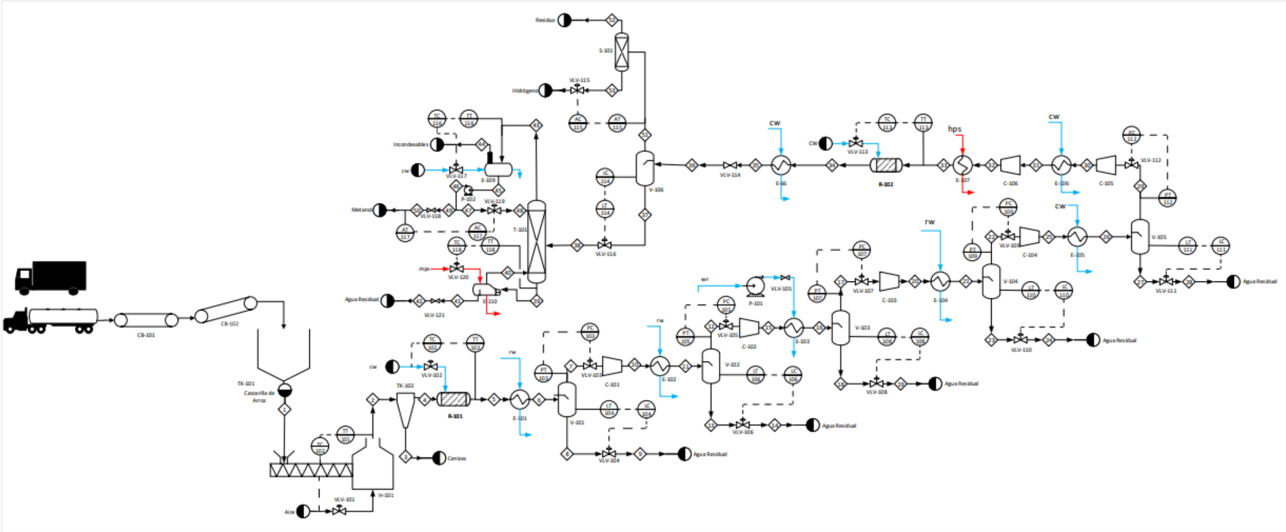

Figure 2. Evidence of a process diagram and instruments to produce ethanol and methanol using rice husk

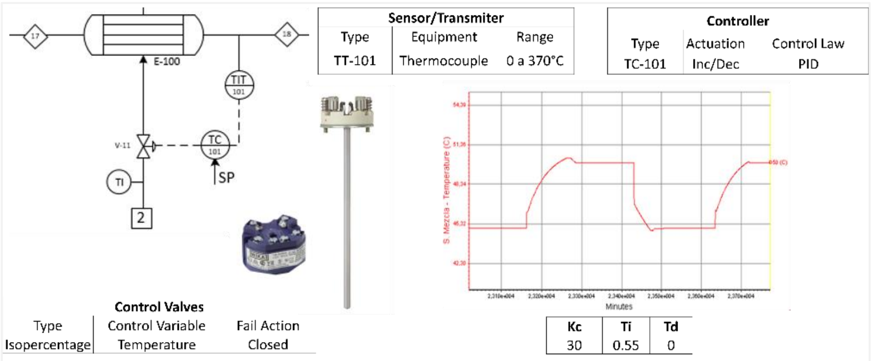

Figure 3. Evidence of instrument selection, definition of controller actions, and controller tuning for the dynamics of a capstone project

From this evidence, the group of professors involved in the capstone has learned lessons regarding the teaching about the elaboration of process and instrumentation diagrams. In particular, the need to strengthen the plumbing rules in class, especially in the location of the final control elements, and deepen the tuning methods and decision-making processes for the selection of equipment. Since software such as HYSYS handles autotuning methods routines, it is necessary to deepen the knowledge of autotuning methods for commercial controllers.

3.3 Evaluation of the results

Using computational tools, it was evidenced an improvement in the levels of competence in the integrated courses. Greater mastery of the topics was found in the presentations and greater participation of students in active learning experiences. The external evaluators have recognized the relevance of the results obtained and have given feedback to the students about their professional training process, in general.

In an opinion query carried out on the graduates of the UPB Chemical Engineering program in the period between 2016 and 2019, it was found that 94% consider that it contributes to professional practice, regardless of the professional subject they currently perform, and 78% consider this to be a highly relevant learning experience, as shown in Figure 4.

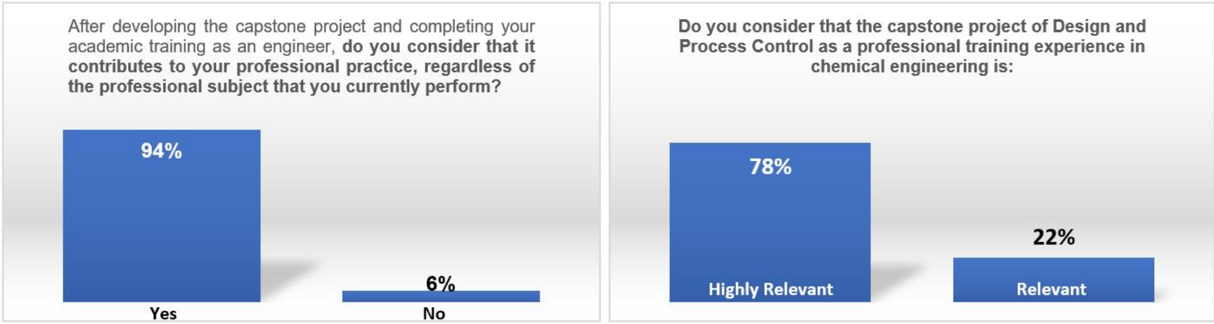

Figure 4. Results obtained in an opinion query carried out on graduates. Sample size: 60 graduates, and two questions via online.

The graduates participating in the focus group, as shown in Table 1, issued a concept about the capstone project. They consider it very valuable to develop in the students an integrating vision of different disciplines of the professional cycle of Chemical Engineering. The construction of a proposal to propose a technical, environmental, social, and economically viable solution to an industrial need or a specific technical challenge is successful. As an integrating vision, capstone covers all the aspects that an ideal Chemical Engineer of the 21st century, as expected in the industry.

The capstone experience was valued as relevant for the students since it brings them closer to reality as chemical engineers. The planning process was highlighted, and they were invited to consider projects related to real challenges for the industries, including advanced technological tools such as machine learning to simulate the synthesis of the processes.

3.4 Opportunities for improvement and next steps

The focus group also made it possible to identify improvement opportunities for the capstone project with the integration of the design and process control courses. The experts suggest strengthening aspects such as the safety of processes in the deliverables, incorporating methodologies for the identification of hazards (HAZID) with an approach to a study of risks and operability (HAZOP); They also suggest the importance of defining and communicating to the students the dedication of the work in hours to the design exercise, according to the level of their training.

Other opportunities for improvement include the involvement of at least one industry sponsor during the development of capstone projects, to generate mini-open innovation challenges in which students receive feedback on the current state of the chemical sector, as well as incorporate within business model projects and value proposals related to the circular economy, the search for carbon-neutral processes, products that take advantage of biodiversity, or that incorporate the principles of green chemistry. This feedback makes it possible to continuously improve the relevance of the capstone project in the training of chemical engineers required by the industry.

4 Conclusions

The Faculty of Chemical Engineering of the Universidad Pontificia Bolivariana developed an integration in the Design and Control of Processes courses to incorporate a project-based learning methodology through a capstone project that has improved meaningful learning for students.

The students showed an improvement in their competencies, by implementing computational tools for the development of capstone projects in the courses, strengthening capacities to investigate, make decisions to design, and integrate control concepts in the development of basic process engineering.

Some strategies were implemented to improve student's learning of the design and control of processes, which involve external evaluation before expert in design, operation, and process control in the industry. The learning results allowed to improve the development of the integrating courses. In particular, the stability, controllability, and tuning of PID controllers.

94% of graduates in that period recognize the capstone project and the project-based learning methodology as valuable and relevant aspects for their professional development.

The focus group with five graduate experts in chemical engineering validated the relevance of the integration design - process control to develop capstone design projects. The experience was valued as relevant, and opportunities for improvement from the weakness were identified in topics as process safety, linking with members or sponsors of the industry, and incorporating themes related to green and sustainable chemistry in the design proposals.

As weakness from the evidence, they were identified more attention on the plumbing rules, especially in the location of the final control elements, and deepen the tuning methods and decision-making processes for the selection of equipment. Since software such as HYSYS handles autotuning methods routines, it is necessary to deepen the knowledge of autotuning methods for commercial controllers. The professors involved in the capstone project used this diagnosis as a lesson learned to improve integration between process design and control courses.

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Cases for teaching and learning assessment planning: a study in the perception of teachers and students from two Brazilian universities

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Abstract

When applied in the classroom, the teaching cases, generate an opportunity, considering the aspects and particularities involved, to study the assessment planning of learning with the adoption of this methodology. The work aims to describe the planning process in the application of learning assessment when adopting the teaching case method in administration courses. This is a multicase and exploratory study, with a qualitative approach, in two federal institutions of higher education in Brazil. The data collection instruments consisted of conducting semi-structured interviews with 10 teachers and 53 students who had already gone through subjects that had the application of the teaching case, with the sample being defined based on the theoretical saturation criterion. The technique for discussing the data was content analysis, also supported by the Iramuteq® software, adopting, a priori, the following theoretical categories: forms of assessment (Fernandes & Fialho, 2012) and time of assessment (Tormena & Figueiredo, 2010). The results showed that when comparing responses of teachers and students surveyed that students and a part of teachers value the form of assessment adopted, especially the students' discussions in groups (Hoffman, 2014). Another part of the teachers uses the assessment based on an expected response pattern (Roesch, 2007), whether it is defined a priori (Albertoni & Silva, 2018) or made more flexible. Regarding the evaluation moment, the teachers elaborate the teaching plan and present it to the students. Students corroborate with teachers when they cite group discussion as a form of assessment, as well as report the need to make a decision to find solutions to the proposed problem (Graham, 2010, Soares et al. 2019). This work is concluded by understanding, although summative assessment methods are used when teaching cases are applied, formative assessment is an option in the planning of useful tools in the development of new skills.

Keywords: Teaching Case Method; Learning Assessment; Administration Teaching

1 Introduction

The worker's pace of work makes his practice less reflective (Mintzberg, 2010). This reality is also a reflection of teaching historically based only on reproduction and had to transform itself so that the professional develops skills of understanding, critical analysis and reflection in a competitive market (Sauaia, 2013, Kakouris, 2015). In this context, Silva, Oliveira and Mota (2013) highlight the case method for teaching as one of the strategies of the learning system in action for the teaching of administration. From the practice of methodologies such as the case for teaching, it is necessary to plan and apply other forms of evaluation that can cover weaknesses of the methods evaluated until the applicable knowledge (Mansur & Alves, 2018). On this subject, Consolaro (2005) assumes that the learning objectives planned by the teacher must be intertwined with the assessment, student development and emphasizing the quality of individualized advancement. Therefore, it is necessary to take into account the importance of planning and carrying out the work proposed by the teacher.

2 Case method for teaching and the learning assessment planning process

Gil (2004) conceptualizes the case method for teaching as reports used and studied by individuals or groups to solve problems and make decisions. For Araujo, Rejowsky and Leal (2012), it is a methodology that describes a real problem faced by a person in the organization, usually presented from the point of view of the decision maker, in order to take this situation to a learning context, inviting people and students to reflect and position themselves in the context presented. For the student to be able to position himself and put himself in the role of the decision maker to find the solution to the problem presented, it is necessary that he has sufficient theoretical foundation to apply theory to practice and solve the problem presented, avoiding the risk of be based on 'beliefs' (Christense, 1987).

Miranda (2008), when studying the evaluation of learning through teaching cases in graduate courses in business, describes the learning process in three stages: a) individual preparation of the student: familiarization reading, complementary readings, diagnosis of the problem, development of alternatives, definition of criteria, proposal of solution; b) group discussion (Mendes, Trevisan & Souza, 2016), where there is an opportunity to debate individual positions and advance the level of understanding; c) plenary discussion, where the understanding of the case develops.

Therefore, it is necessary to take into account the importance of planning and carrying out the work proposed by the teacher. One of the ways to carry out this planning is from the elaboration of the teaching plan built at the beginning of the discipline (Silva, Santos & Paixão, 2014). The plan helps the teacher to organize the necessary resources for the classes and favors the monitoring of the activities that will be developed (Tormena & Figueiredo, 2010). This avoids improvisation, facilitates the integration of students with learning experiences, so that the student's vision is broadened, cooperative, participatory and this develops autonomy in learning (Sassaki, 1997, Nogaro, 2018).

When carrying out the planning of his classes, the teacher chooses the evaluation method he will use, decisively influencing the way the students will direct their studies. This choice will serve as a parameter for the student to plan the time he will dedicate to his studies, define the contents and priorities to be learned and determine his degree of engagement in academic activities (Silva, 2015).

Luckesi (2011) also states that the evaluation of learning will only be successful if in its planning there is clarity in what it aims to achieve, if it shows the commitment and investment of those who perform the act of evaluating and if it contributes to the investigation and the transformation of practices pedagogical. The author states that the evaluation must be procedural, dynamic and constructive in order to subsidize the teacher so that his / her action is as appropriate as possible, prevailing the student's learning.

3 Methodology

This is a multiple and exploratory case study, with a qualitative analysis approach. In this perspective, the present study investigates the perception of professors and students at UFRN and UFPB who use the case method for teaching in their disciplines. Ten teachers from the two institutions were interviewed. In addition, the second group consisted of fifty-three students from UFRN and UFPB. Data processing was carried out through content analysis, where the categories of analysis emerged from theoretical support: forms of assessment (Fernandes & Fialho, 2012) and time of assessment (Tormena & Figueiredo, 2010). Finally, for data analysis, a reading of the comments transcribed in the interview was carried out, aiming at coding and grouping the text units - in order to carry out a more assertive analysis of the teachers' comments and in relation to the students, the Iramuteq® software was used. to assist in the analysis of responses and contemplate the objectives to which the present study set out.

4 Analysis of Results

In order to maintain the anonymity of the respondents, a codification was established for the subjects and their speeches, distinguishing them between participants from Rio Grande do Norte and Paraíba. Thus, the “P” code represents that the respondent is the teacher. The acronyms RN were added to the end of the teachers' codes to facilitate the identification of teachers in Rio Grande do Norte and teachers in Paraíba - PB, varying between PRN and PPB.

For the students, other codes were defined, where "A" means that it was a testimony from a student. Like the teachers, the acronyms of the states, where Rio Grande do Norte - RN and Paraíba - PB, were also added to the students' codes, varying between ARN and APB. The question applied with teachers and students had the objective of identifying how the learning assessment planning occurred in the application of cases for teaching in the discipline taught. The results of the interviews carried out showed that all professors interviewed at UFRN and UFPB plan, in some way, the evaluation process applied in the classroom. When affirming that they plan the evaluation, it is possible to perceive as one of the contributions of this research that, according to the speech of the teachers, they carry out the planning in two ways: the first group values in their testimonies that they prefer to plan their evaluation considering the forms of assessment that will be applied in the classroom. In the other group, the teachers focus on the moment or period when they will apply the assessment, thinking and planning each activity at the beginning of the discipline, that is, before it happens.

In this sense, the studies by Zanon, Kailer and Althaus (2017) state that in order to use evaluation strategies well, it is necessary, first of all, to plan teaching situations. Complementing this thought, Tormena and Figueiredo (2010) point out in their research that they are the actions previously planned that will improve the performance of the teacher in the classroom when applying the assessment. In relation to the first group, as reported in the teachers' statements, they value the forms of evaluation in their assessment planning when they apply cases for teaching - that is, they did not detail the period of time in which they planned the evaluations, but described the moment of the application of the evaluation.

On this subject, research by Depresbiteres (2010) points out that it is important that the form of evaluation is chosen according to the objectives that one wishes to achieve. In the same sense, the studies by Fernandes and Fialho (2012) state that, in general, teachers use different forms of assessment, not limited to tests. Continuing with the forms of assessment reported by the respondents, another group of teachers was identified, five subjects, one from UFRN and four from UFPB, who carry out evaluations based on student participation, when they are discussing in small groups, and then expand the debate for a large group discussion, according to the excerpts from the statements below.

"[...] then students can discuss in groups and then we take a larger approach with the whole room and then I make theoretical connections and clarify some concepts" (Prn2F1). “[...] we do the discussion in small groups and then do the discussion in the plenary” (Ppb10F1). “[...] they divide it into groups, they debate the answers in groups and then, they get the whole group together so that we can arrive more or less at a common denominator, more or less” (Ppb6F1) “[...] I never worked individually, I worked in a group” (Ppb8F1). “At first, the participation of students and their involvement in small groups, right? When we separate the class, go to the groups and pass the questions, pass the case and pass the questions. So I evaluate the interaction between them, you see the participation of everyone, a circle between the groups observing the interaction, participation and contribution, you know. This is a first step. In the second moment, it makes a large group and then again I evaluate the general participation group by group and individually in the resolution of issues ”(Ppb9F1).

In the reports presented by the teachers, it is noticed that they carry out activities that involve student participation, both in small groups and in plenary discussion, so that the student himself can interact, argue and discuss the solutions of the case and learn during the debates. The excerpts from the speeches corroborate the studies by Miranda (2008) who point out that in discussions in small groups and in plenary there is an opportunity to debate individual positions and advance the level of complete and detailed understanding of the case. In this way, when the teacher describes the student's participation in the discussions, using this to evaluate him, according to what the studies present, he helps the student to position himself in the discussions, to place himself as the decision maker, reflecting on the problem and understanding the situation presented. Another format of evaluation planning found in the research results was to carry out based on an expected response pattern. In this research, this evaluation format is subdivided into two groups of teachers, namely: one that is based on the response pattern defined in the teaching notes and the other that values the same response pattern, but that this can be made more flexible from of the new solutions for the case found by the groups of students. Thus, the research subject who relies on the response pattern defined in the teaching notes, a professor from UFRN, reports in his speech that

"I carry out the evaluation based on the response that the students give to the case, establishing standards for the expected response" (Prn3F1).

The teacher expects the student to answer the questions present in the case and to evaluate them according to the response patterns that are in the teaching notes. Students should realize, according to the studies by Roesch (2007) and Marion and Marion (2006), the possible solutions to the problem reported in the case, since there is not only one answer to the dilemma presented and choose the one, he believes to be the most suitable.

It is understood, therefore, that there may be solutions pointed out by students that are not included in the answer keys, that is, students can give a different solution than the one the teacher already expects. However, there was no evidence in this professor's speech that he was open so that, perhaps, some solution would be different from those that were previously established. The excerpt of the teacher's speech is in accordance with the studies by Roesch (2007), when he points out that the teaching notes must contain questions for the discussion of the case and must be well formulated to arouse the interest of the discussion and stimulate individual and group learning. In addition, research by Albertoni and Silva (2018) states that the author must specify alternatives for the analysis of the case, presenting the theory used to substantiate the case and that will serve as a basis to guide the answers to the questions proposed in the classroom.

Just like the research subject Prn3 in his F1 speech, there is one more teacher who also evaluates based on a response pattern, but who is flexible to accept the different solutions given by students different from those shown in the teaching notes. It is worth noting that in the case method theories, no record was found that talks about this flexibility in the responses, as reported by the subject Prn4 in his F1 speech below. Therefore, this subcategory emerged from the data collected and analyzed in this research. Thus, the expected response pattern serves as a general parameter in the evaluation process, although it does not impede the innovation capacity of the group of students, allowing an opening in the evaluation process to contemplate, in addition to the response options suggested in the teaching notes, other additional elements that were considered and discussed by the group, since

"There is no punctual answer, there are some indicators that we will follow to try to guide the rationality of the decision. But eventually this is open, the solution that the group may be able to refer is completely different or different from the referral of another group". (Prn4F1)

The teacher reports that different solutions given by the groups are expected. In this way, assessment is not compromised and allows the student to seek, even, the resolution of the case from contents seen in other disciplines, in addition to those used in the case. The teacher, therefore, uses the indicators in a flexible way, that is, if perhaps a student or group resolves the case differently from what he expects, this solution may be valid. Still in relation to planning based on the forms of assessment, another subcategory found in the study and in the testimony of a professor at UFRN was that he conducts the assessment based on a self-assessment he adopts with his students.

"E também temos a auto avaliação deles ao final do semestre do que temos visto dessa área, então a gente também tem de certa forma essa avaliação. Então a gente também solicita que eles avaliem, deem o feedback deles, tanto no momento do caso, que tem aquela reação imediata, né, que a gente chama de avaliação da avaliação, como também pra avaliar no final o que, o que é que na aplicação desses casos contribuem para a aprendizagem deles" (Prn1F1).

Different from the perception of this previous group of teachers, - in the second group, focusing on the moment of the evaluation, two professors from UFPB carry out the previous planning of the evaluation in a systematic way. The excerpts of the speeches of the teachers that register this planning format can be verified in the testimonies of the subjects, when they comment that

“I usually deliver a lesson plan, where they already know the days, they have activity because I score all of them, you know, I don't just take tests, I like to do continuous assessment and I use the case not only to bring the student closer to the practice, but I also do an evaluation with him. [...] Planning is always prior”(Ppb7F1). “They know, oh, you will be evaluated like this, they know everything, the whole process, before, well before, they don't know before, they know well before, they know about the whole evaluation process and how much the case will weigh in their evaluation in the discipline's learning process. They know everything so as not to have improvisations ”(Ppb5F1).

The reports showed that they value the importance of planning carried out a priori in relation to methodological choices and evaluations carried out during the course of the disciplines. The speeches of the teachers confirm the results of the researches carried out by Sassaki (1997), Menegolia, Santana (2001), Le Boterf (2003), Nogaro (2018), when they affirm that it is necessary to carry out a planning, thus avoiding the improvising and facilitating the integration of students with learning experiences. The moment the teacher makes the prior planning of his classes, he chooses the most appropriate assessment method that he will use for each moment of the discipline, according to the programmed content and passes on this information to the students. Of the teachers surveyed, this was the only one that cited this evaluation format different from the other respondents. It is noted that, although other teachers mention types of formative assessment, this researcher pointed out that he uses a method of formative assessment that is not centered only on the teacher, but aims at self-criticism and co-responsibility in relation to the student's intellectual development.

In the self-evaluation model, the teacher expands the evaluation format used, since not only does he evaluate, but the student also actively participates in the process, self-evaluating himself, analyzing his evolution in relation to the learning process, his responsibilities in this process and the needs to reach the desired goal. Self-assessment, therefore, is no longer just the assignment of a grade to be an analysis of a path taken and all that it means. The excerpt of the teacher's speech is in the same direction as the research by Gobbo, Beber and Bonfiglio (2018), when they point out that self-assessment guides students, giving reference points and directions to follow, once the student revisits their work and participation , identifying obstacles and needs for improvement in their learning process.

Figure 1. Planning the application of teaching cases in the students' view (word cloud)

The word most cited by students in relation to the question of planning carried out by teachers in the application of cases for teaching was the word "group", followed by the word "discuss". Following these two terms, the words “debate”, “reading”, “solution” and “decision” also appeared. The excerpts from the speeches of the UFRN and UFPB students confirm this statement.

“We discussed the issues in small groups, went to the larger group to discuss the best solution to that problem and make a decision. these issues to bring to the group and then with the group.” (A7F2)

"[...] we discussed in groups and then discussed with the rest of the teams about the case for teaching and there were also those where each group, each team, we received a different case study." (A19F2)

“At first she passed the cases on to teaching, she posted on SIGAA, then she did a previous reading and everyone arrived to discuss in the groups and then in the group.” (A20F2)

“[...] most of the teachers gave the case for teaching in writing for us to do the reading. [...] debated in groups and then we presented one or two solutions or to the whole room in which we could discuss.” (A21F2)

“[...] he asked us to get together in a group, read the case and show how we would solve that situation.” (A29F2)

“[...] the teacher sent him the case, before the class, so that we could do his reading and study, that is, during the class, a dynamic reading was usually done. [...] the application was generally divided into groups. we were placed in groups based on the number of students in the class.” (A34F2)

“[...] the teacher gave the text with the case, a week before, then we read individually, answered some questions and then in the classroom we formed groups, discussed the case, answered the questions in groups, sometimes some disagreed with the other's opinion, but it was very interesting.” (A36F2)

“First, the teacher passed the case on for us to read, usually at home, in the classroom, divided it into groups, to discuss the issues of the case, because the case always ends with some questions to answer a topic, and it was debated in groups, then the teacher resumed, discussing in general what the results were and answering the questions.” (A44F2)

The words cited by the students are very related, that is, when they spoke in a group, they immediately cited discussion, as did the terms debate and reading. Students report the discussion of cases in small groups to answer the proposed questions and then discuss in the large group the various solutions found. The excerpts from the speeches are in agreement with the findings of Cobb and Yackel (1996) who state that one of the ways to accompany students is group work, which promotes interaction between students when they need to negotiate meanings and interpretations in search of consensual or compatible forms of understanding in and through social interactions. Another term mentioned by the students and that is present in the word cloud is “solution”, according to the statements.

” Usually he passes a data to us with a problem for us to solve, we usually discuss these activities in groups, try to find the solutions, the most likely ways, I don't know, within what we know and formalize with the teacher and he evaluates it later. ” (A9F3)

“I read all the texts that we had to use as the basis for the activity where we were going to answer a question based on a real case that really happened. And based on that, we would have to provide a solution that does not exist right or wrong, but a correct answer based on each situation.” (A13F3)

“He brought some teaching cases for us to analyze and find the most viable solution to the company's problem.” (A24F3)

“[...] the teacher delivered the paper with the case for teaching, you know, and asked us to give an opinion, how we would solve that situation, what would be the most viable solution.” (A28F1)

“[...] she divided the class in two and each of the classes went to defend a different idea looking for the points, pros or cons, or defending each aspect of the case presented to find the most appropriate solution to solve the problem. " (A43F1)

The students report that the teacher, when applying the methodology of the case for teaching, asks them for possible solutions to the problem of the presented company, leaving the students to occupy the position of company administrator, solving the problem, bringing the reality of the company closer to the classroom of class. It is noticed that the teachers accepted the solutions presented by the students, even if they were not the same ones that were suggested in the teaching notes of the case at the moment when statements like “we would have to give a solution that does not exist right or wrong, but a correct answer based on each situation.", "find the most viable solution to the company's problem "," find the most appropriate solution to solve the problem. "

The statements corroborate the studies by Graham (2010), Clemente Junior (2012) and Soares et al. (2019) for those who do not have a single correct answer for the teaching case, even allowing the confrontation of opinions between the students who propose the solutions. Another term that appeared in the word cloud related to planning was "decision", which is directly related to "solution", according to the statements.

"[...] the teacher put a type of activity at home, for the student to develop in the decision-making process within the scope of the Administration." (A29F4)

"So you had a storm of ideas that later you had to combine them all and make a conclusion from it, make a decision within different ways of analyzing, different ways of thinking." (A46F4)

"[...] we needed to decide this, he gave us eight days, gave all the data, the details and we each needed to take his opinion, what he would do, what was his decision as an administrator." (A53F4)

Students affirm that they need to make decisions to find solutions to the problem presented in the case, which corroborates the research by Spricigo (2014) when he affirms that methodologies, such as the case for teaching, that are based on real situations are powerful to develop in students' skills and abilities related to decision making and problem solving.

In the same sense, the observations of Soares et a. (2019) point out that the teaching cases describe realistic and sufficiently complex situations and problems that have multiple skillful decisions to solve problems, engaging students in "real world" problems, promoting good discussions in search of understanding about what would be the best decision to be taken to solve the problems proposed in the case.

Even though it was not mentioned by many students, but considering the context in which the students answer the planning question, narrating about the way the teachers apply the case, a term that can be analyzed related to the first question of the data collection instrument of the students. students is "experience", according to the statements.

"It was an interesting experience, because we had not yet passed and even that motivated some students to write, in the following period, their course completion papers in this format of teaching cases." (A43F2)

"[...] the teacher already had an experience of applying cases, including he also guided students to build cases for teaching and the experience was very positive because the students were motivated to write cases on the tcc." (A47F1)

The students report on the positive experience of having the cases for teaching in the classroom and that, after that, some students were motivated to write a case as a course conclusion work. The student's interest in the experience of the teaching case may be linked to the fact that it is a different methodology from the conventional teaching methods that he is used to dealing with in most disciplines. In the case of teaching, he occupies the position of manager to make decisions related to real problems, an opportunity to get closer to professional practice. The fact that students are interested in building cases for the end-of-course work may be related to the student having lived some experience that serves to build a case. In addition, the methodology brings students closer to professional practice and allows them to solve in the classroom issues they experience in the job market, as pointed out by Soares et. al. (2019) It is noticed that only UFPB students report the experience of having colleagues who choose the construction of a case as an end-of-course work. This is due to the Administration course at this university having among the options of final works the cases for teaching, according to UFPB (2016).

4.1 Summary of research results with teachers and students

Regarding evaluation planning, the teachers' response is divided into two large groups: the majority, nine of them, answered the question by citing the forms of evaluation that they perform in the classroom when applying cases for teaching. These forms of assessment included the participation of students in groups, the correction of case responses according to a defined standard (which can be a priori or made more flexible) and assessment through students' self-assessment. Only one teacher reported that he carries out the planning in a previous and systematized way. When comparing this question with the students' answers, they all talked about how the teacher applies the assessment of learning and the majority cited the participation of students in the groups as a means of evaluating, confirming what was said by the majority of teachers. This demonstrates, comparing the general result of students and teachers, that the planning of the evaluation system includes a participation of the groups, being adopted by most of the teachers in the classroom, although there are some different forms of evaluation mentioned by only a few students: solving the problem of the case and making a decision.

It is noticed that this type is not in the forms mentioned by the teachers, because the solutions are found in groups, therefore, this way of evaluating is inserted in the participation of the students in the groups mentioned by the teachers. It is also understood that decision-making is also inserted in the discussion of students in groups, so this item can also be inserted in this form of assessment mentioned by teachers.

It is understood that the students mentioned the ways of evaluating in a more detailed way because they do not have the planning and evaluation experience that the teacher has. For the teacher, evaluating the student's participation involves verifying the solutions given to the case, observing the student's position as a decision maker, but this does not need to be detailed because thinking and structuring his classes and, consequently, evaluations is an activity present in the teacher's daily life, while the student does not have this practice and for that reason he details his response regarding the performance of the activity. The students also reported on the positive experience of participating in moments when teaching cases are applied, to the point that some students choose to build a teaching case in their course completion work.

Despite being mentioned by a small part of the students, the positive experience demonstrates the students' interest in using active teaching methodologies, such as the case for teaching, and to know the method in more depth, resulting in the construction of cases for work end of course. On the other hand, it is understood that, because it was mentioned by few students, this positive experience did not attract the attention of teachers to the point of being present in their answers.

5 Conclusion

This demonstrates, comparing the general result of students and teachers, that the planning of the evaluation system includes a participation of the groups, being adopted by most of the teachers in the classroom, although there are some different forms of evaluation mentioned by only a few students: solving the problem of the case and making a decision. It is noticed that this type is not in the forms mentioned by the teachers, because the solutions are found in groups, therefore, this way of evaluating is inserted in the participation of the students in the groups mentioned by the teachers. It is also understood that decision-making is also inserted in the discussion of students in groups, so this item can also be inserted in this form of assessment mentioned by teachers. It is concluded that teachers use summative and formative assessment methods in teaching cases, assisting in the professional training of students.

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Communication and alignment of expectations in implementing a PBL proposal

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Abstract

Communication is a factor that can influence the success of projects, especially when several partners are involved and their joint action is necessary to achieve results. The implementation of a curricular change is one of those situations, because it is planned by curriculum managers, but will have as a final focus the work done by the students, who are the agents in the learning process and will make use of the experiences and strategies created for the curricula. Although the curricula are created based on the needs raised with students and teachers, their implementation requires a clear communication of objectives, teaching and assessment strategies, in addition to constant monitoring throughout the process, so that any adjustments can be made quickly, correcting the route in case of failures. This communication should ensure consensus on the purposes and engagement in the learning activities. Five years after the start of the implementation of a curricular proposal in an engineering school, which introduced the use of projects in parallel to the course subjects, two surveys were carried out, one with teachers and the other with students, and both showed the existence of doubts about the purpose of the changes introduced, which can be attributed to ineffective communication. The curricular change is consolidated and is valued by both teachers and students, however better results could have been achieved if there was better communication, which would make the experience more successful and, even, making the participants the best disseminators of this experience. This work analyses the communication aspects of this curriculum, based on the data from the two surveys, to identify problems and suggest actions.

Keywords: Project-based learning. Communication of the curriculum. Curricular change. Teacher conceptual change. Active learning strategies.

1 Introduction

The construction of a pedagogical project is something that arises from the moment that different demands contribute to its elaboration. Project Based Learning is a strategy that meets the demands for changing curricula in engineering courses. The change to these strategies is motivated by government agencies or by the universities themselves, to be aligned with employers, professional bodies, international influences, students, universities and governments, who with their policies coordinate the infrastructure to support engineering programs (Powell and Weenk, 2003).

The creation of a new curriculum is prepared by a team, considering the perception of everyone involved in the process, such as managers and teachers. Thus, the motivation and details of the new curriculum could be shared, making it a collective construction. In its implementation, when the curriculum is operationalized (Pacheco, 2005), the students join the various actors, and among them there must be clear, objective, efficient and effective communication so that adjustments can happen throughout this process. In the case of students, as they are the main elements of the learning process, the rules and agreements of the new curriculum must be made explicit in order to bring together all stakeholders and align training goals and expectations.

To discuss the issue of communication in the alignment of a curricular change, we will use the experience in an engineering school in which the team of teachers had the responsibility to create projects that promote the development of desirable competences to the students as: prepare them to interviews in a selection process, develop attitudes in a possible negotiation, be a leader on several occasions, among others, that meet the current National Curricular Guidelines - DCNs - for these engineering courses in Brazil (MEC, 2019).

This work emerged from the perception that the communication in the implementation of a curriculum was not adequate, and that the misalignment was perceived by teachers and students, which caused difficulties in the implementation of the curriculum proposal. Pointing out this type of problem can help in other types of experiences, promoting clear communication and with a better engagement of students, turn them more familiar with the new curriculum.

2 Theoretical References

The development of the curriculum involves procedures and, above all, people who collaborate and cooperate for its good implementation. Goodlad (1979) indicates that the curriculum goes through different levels with the 'ideal curriculum' being the beginning of the process, and ends with the "perceived curriculum", which is experienced in daily school activities. The perceived curriculum can be evaluated in surveys carried out with students and teachers after its implementation process. Thus, it is possible to identify possible gaps, as the communication between the interlocutors of this process - management, teachers and students.

The engineering programs in Brazil follow the National Curricular Guidelines (MEC, 2019) which orient undergraduate engineering programs in many dimensions. These guidelines indicate that engineering training aims to provide the future professional with several competences [12]. Among them, "Effective written, oral and graphic communication" stands out.

Communication is important to engineers because ask for to someone in a clear and objective way is the key to achieve what do you want. Likewise, knowing how to listen is the possibility of understanding the other and being able to directly offer what he wants. In addition, graphic expression, as an important part of communication, is fundamental for world modelling. Not to mention the ability to communicate using the voice, which in times of online activities has is very important, and is practiced in front of a computer screen. Thus, communication, whether oral, graphic or written, must be developed by engineering students.

The PBL integrates technical and transversal competencies to solve engineering problems and to fulfil the requirements imposed by professional contexts (Mesquita et al., 2013) and communication is one of those required competencies (Pascail, 2006; Lima et al., 2012). Silveira (2008) highlights some advantages that can be obtained with PBL, as "improves communication, organization, presentation, management, research, questioning, self-assessment, reflection, relationship skills and group leadership".

For all these reasons, good communication with students regarding the objectives of the projects used in the teaching-learning process, clarifying their contribution to the development of competences is the primary action to guarantee the development of communication skills (Mattasoglio Neto, et al., 2019).

3 Research method

This work uses part of the data from two surveys carried out with two different groups, one of professors and the other of students, both from the same engineering courses in which the projects were offered as complementary activities.

The data were obtained with questionnaires created in Google forms whose links were forwarded by email to each group. After then, they were worked in an Excel spreadsheet, which allowed the analysis of several dimensions, including communication. The questionnaires were sent to teachers and students from various courses at the school, and eight teachers and ninety-two students answered the questionnaire.

In the original research, different dimensions of analysis were considered with both teachers and students, and from these dimensions emerged the perception of the failure to communicate the curriculum goals to students, which is the focus of this work.

4 Findings

Data analysis and discussion are indicated in the items that follow.

4.1 Characterization of the samples

In the group of eight teachers five of them are male (62 %), and most are between 40 and 50 years old (75 %). All respondent teachers agree on the importance of using active strategies in learning, which are the ones that support the projects.

In the group of students, 41 % are male and 55 % are enrolled in daytime course, knowing that the school offers the courses at nocturnal again. The vast majority of respondent students are still students of the institution, as can be seen in the Table and at Table 2 it is observed that the different program in which the students are enrolled.

Table 1 – Series attended

Series	% of respondents
4th annual period	35,0 %
5th annual period	28,0 %
6th annual period	27,0 %
Already concluded	10,0 %

Table 2 – Percentage of respondents by program

Program	% of respondents
Industrial Engineering	28,3 %
Chemistry	20,7 %
Civil	26,1 %
Electric	6,0 %
Food	14,1 %
Automation and control	4,3 %

4.2 The initial communication to presentation projects and expectation of projects

All teachers interviewed perceive the projects as generating improvements in the courses and 13 % identify that the projects are not directly linked to the technical content of engineering, but rather focused on the development of skills desired by the job market and related to behavioral aspects, soft skills.

For students, the projects met their initial expectations (80 %), but there is a need for adjustments to make them more aligned with these expectations (Figure). This indicates a small misalignment between what is communicated to students at the initial presentation of the projects and what is actually offered to them. Figure 2 shows that 75 % agree that the initial objectives have been met and 13 % disagree, what confirm this misalignment between the objectives presented and perceived by students.

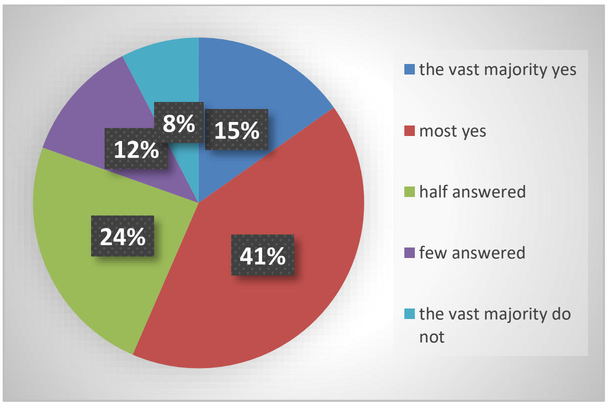

Figure 1 – Expectation of students were achieved in the projects

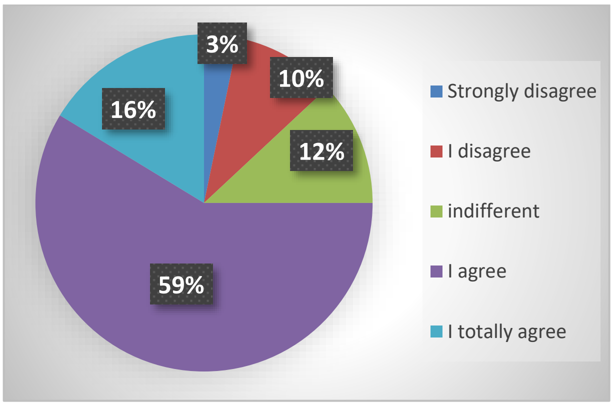

Figure 2 – The objectives initially presented were achieved

4.3 Communication of projects on the point of view of teachers and students

Figure 3 brings the teachers' perceptions about the maturity of the students to realize the value of the projects in the curriculum. Along with this, 75 % of teachers have doubts that students understand the role of projects in the curriculum proposal. (Figure 4).

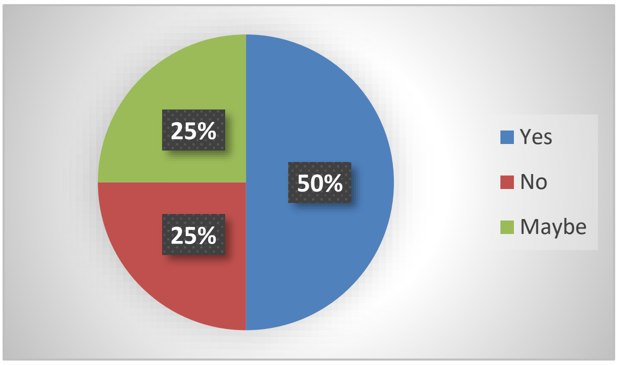

Figure 3 – By teachers, the students maturity to understand the importance of projects

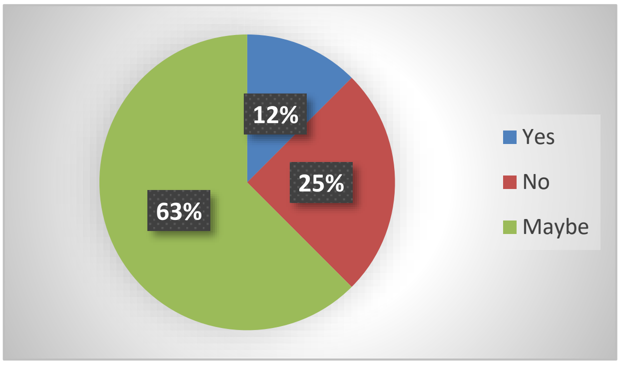

Figure 4 – In the teachers views the student is aware of the objectives of the curriculum proposal implemented

To the teachers, the students do not realize the projects and the importance of active learning, which is the main strategy used and, in addition, they do not have knowledge about the implemented curriculum proposal. This leads to the perception that students only fulfill projects with the aim of achieving approval.

It was asked to students if there was good communication about the projects, 39 % said yes and 25 % said no, 36 % had doubts in the answer (Figure 5). When asked if they understood the real importance of the projects in the context of the course, which 73 % stated that they knew, 17 % had doubts and 10 % did not know the real purpose (Figure 6).

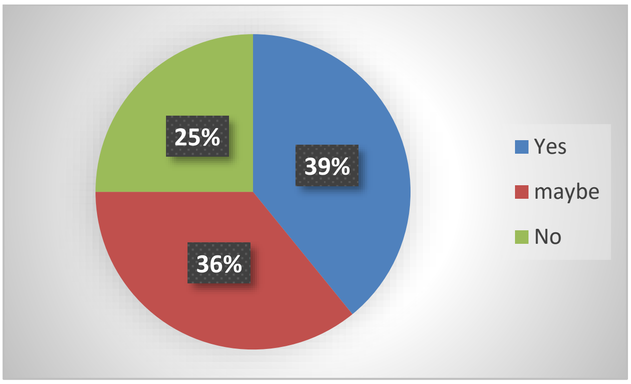

Figure 5 – To students - there was good communication about the projects with the students

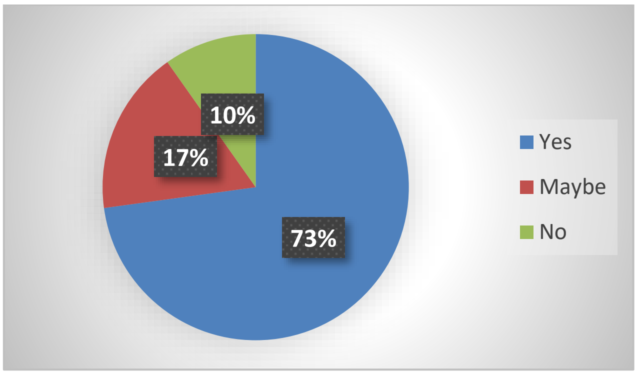

Figure 6 – To students - Do you understand the purpose of the projects in the context of the course?

The perception that the projects were not properly communicated is explicit and points to the need for an action aimed specifically at promoting a clearer disclosure about the projects, their objectives and the strategies used in carrying out the activities. In a sample of 92 students and alumni, all experienced in the course, there is a high rate of those who indicate that the communication about the projects is poor and 10 % of the students do not realize their real importance in the context of the course.

There is a difference in responses between teachers and students. Teachers say that students have no clear perception of what the projects are, while students agree that they have a good understanding about the purpose of the projects. Thus, there is a need for a more careful work of dissemination and alignment between the perception of students and teachers.

4.4 The communication factor as a competence

One of the objectives of the projects is to develop transversal skills, including communication, for a better performance in your future professional activity. When students were asked about the development of the communication competence in the projects (31 %), there is an indication that it is accomplished, and it is among the five most highlighted by the students. The others competences are: teamwork skills (45 %), solving problems (39 %), organizational and planning skills (35 %), creativity (31 %).

Although communication is valued as a competence by students, there is a failure in communication a part of teachers to conduct the curriculum. The students are not fully aware about what and how projects can contribute to their training. So, if a curriculum wants to teach communication, internal communication, especially with students, needs to be effective.

If attitudes are learned by experiencing, good communication in the school environment will promote the training of professionals who value these skills.

5 Conclusion

Although the communication in the initial phase led to the perception that the initial objectives and students' expectations were met, the perception between students and teachers regarding projects diverges.

The results indicate that, to the teachers, students do not recognize the true importance of projects and curricular change and are more concerned with having approval in the work performed instead of being perceived as learning opportunities for the development of skills.

From the research with the students, it can be concluded that the lack of communication is a factor that hinders the development of the projects because 75 % of the students think that there was no good communication and 27 % do not understand the real purpose of the projects.

Still regarding teachers, their commitment and sociability with the students are satisfactory. However, in the conduction of the projects and in the evaluations there are some flaws, which are not necessarily the fault of the teachers, but, as mentioned, it may be linked to the lack of communication.

It can be said that the perceived curriculum has not yet developed an identity in relation to the idealized curriculum, because there is a need of a better communication about the projects' objectives, clarifying their contribution to the development of competences.

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Exploring a BPMS system for learning production management with simulation of manufacturing scenarios

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Abstract

The approach by processes, and business processes management (BPM) in particular, has been increasingly studied by academia and more adopted in the business environment, due to its capabilities. Therefore, educational establishments should consider teaching and learning of technologies (such as BPMS systems) that systematize and facilitate the analysis, design and (re)engineering of organizations. Simulation systems can be used to develop active learning and improve student engagement in engineering classes. This work aims to explore the use of BPM in such a way that it might integrate with pedagogical practices. Specifically, we carry out a preliminary evaluation of a BPMS system in the simulation of manufacturing processes, aimed at the future teaching and learning of undergraduate students on Production Engineering courses, for the assimilation of knowledge about Production Management through life-like examples. The context under consideration was the manufacture of products assuming different physical layouts, which represent the positioning of the transforming resources of a hypothetical production environment, determining how raw material and transformed resources will flow through operational procedures. Using a version of the Bizagi software modeling and simulation, we identify the facility with which the processes are modeled, as well as quick data entry and simulation of these processes, could be modeled with the software analyzed. However, some difficulties in modeling and simulation with Bizagi were discovered with regards to the consideration of manufacturing processes by batch. That is, in this initial investigation of the simulation functionalities of the system, it was not possible to use batches of different sizes. This difficulty limits the use of the BPMS for simulating manufacturing scenario concepts and, consequently, the use of the system for pedagogical activities in production management classes.

Keywords: Process Management; Simulation; Production Management; Active learning.

1 Introduction

There is a worldwide trend for market unification and the globalization of the economy. Because of this, there is a need for companies to find new ways to improve their processes, using, for example, BPM (Business Process Management), whose approach is management of a company by processes. To support modeling, simulation, execution and process management activities, appropriate languages and BPMS (Business Process Management System) tools are required (Cheung & Hidders, 2011; Association of Business Process Management Professionals, 2013; Brocke & Mendling, 2018; Dumas et al., 2018).

Modeling and simulation techniques have been used to better describe the business processes of organizations, and are the basis for the application of other typical techniques of design, operation and company management (Kuchař & Vondrák, 2016; Bisogno et al., 2016; Vukšić et al. 2017).

In classrooms where the course is centered on the instructor, many students lack motivation. They adopt a passive position in front of the teacher and find content, which in most cases does not correspond to initial expectations, fragmented. As a result, they are unable to think analytically.

Modeling techniques and simulation systems have already been used successfully for teaching and learning in various contexts, but there is a lack of work in the area of BPM and Manufacturing Processes. Before using a modeling system pedagogically, it is necessary to create possible models considering scenarios and testing the features of the simulation system to be used.

This work aims to explore the use of Process Based Management in an integrated way. In particular, it aims to carry out a preliminary evaluation of a BPMS module in the simulation of processes aimed at the future creation of possible pedagogical practices for the teaching/learning of undergraduate students on Production (or

Industrial) Engineering courses, using the assimilation of the Production Management content through life-like manufacturing scenarios. More specifically, the functionality of BPMS was tested and analyzed in two different production configurations, associated with two typical layouts from the theory of production management: the functional arrangement (or process layout) and the arrangement by product (or product layout).

The process-based approach and BPM has been increasingly studied by the academic environment and has been increasingly adopted in the business environment, due to its capabilities. Therefore, educational establishments must teach and make use of technologies (such as BPMS systems) that systematize and facilitate the analysis, design and (re)engineering of organizations.

Thus, after presenting the theoretical basis on the subject, this article will present the research method and the development of the work, followed by the results achieved and an evaluation of the use of a BPMS system to simulate production planning concepts.

2 Theoretical Basis

2.1 Business Processes Management

Managing business processes efficiently is critical to the success of an organization. However, such management is more complicated than it may seem, as business processes interact with each other. And yet, the more processes are managed, the greater the potential for them to bring benefits and results for a company (Tarhan, Turetken & Reijers, 2016; Brocke & Mendling, 2018; Dumas et al., 2018).

According to Minoli (2008), the objectives of BPM are to understand the different business processes of a company; restructure the processes in order to optimize their operation based on the knowledge of processes; and assist in decision making, thereby supporting the interoperability of business processes.

BPM practices lead to an organization centered on processes, reducing its dependence on functional and territorial structures. The benefits offered by BPM are: continuous improvement and innovation, visibility, compliance (acting in accordance with the rules), standardization, greater agility, teamwork and cost reduction (White & Miers, 2008). Among several BPM cycles proposed in the literature, Baldam, Valle and Rozenfeld (2014) created a Unified BPM Life Cycle for process management, which is composed of four phases (Figure 1). The mapping, modeling and simulation of processes are carried out mainly in the Process Modeling and Optimization phase.

2.2 Mapping and Modeling of Business Processes

The objective of process mapping is to identify and understand all activities in an organization, thereby establishing its design as it is; and from that information, to improve or modify it, in order to arrive at the way you want it to be (Assunpção, 2018). Some basic options for gathering information for analytical processes, being considered good practice for the management of business processes, are: observation; interviews; simulation; and do rather than observe (Association of Business Process Management Professionals, 2013). However, there are more appropriate methods for mapping processes, such as SIPOC (Suppliers, Inputs, Process, Outputs, and Customer). It is a simple language graphic that defines the process map, the purpose of which is to identify processes and management so that everyone involved understands their responsibilities.

The mapping activity in the literature overlaps, or is confused with, the modeling activity for some authors and research context, since documenting the information gathering of mapped processes is necessary, that is, process models end up being the results of the mapping. Simply put, Mertins and Jochem (2005) define models as reference guides for support and documentation throughout a project, improvement or reengineering of a company.

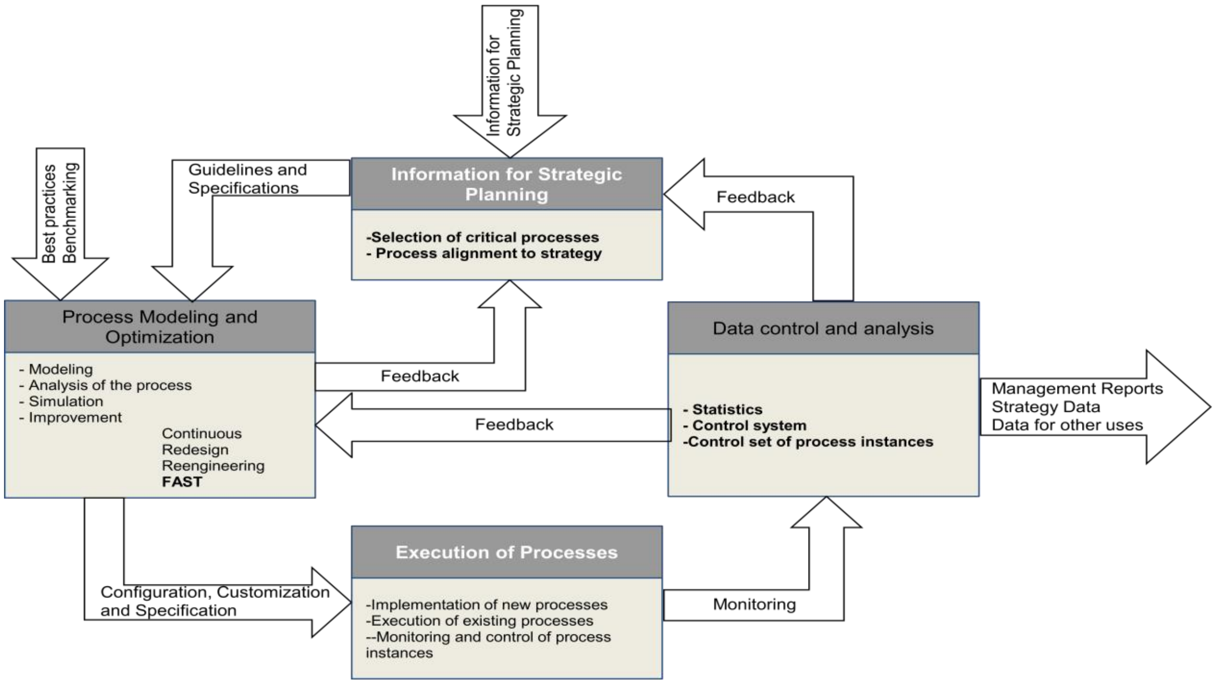


Figure 1. Life cycle for the BPM (adapted from Baldam, Valle and Rozenfeld (2014).

Business process modeling is a way of organizing work and resources - whether people, equipment or information - in order to achieve an organization's objectives. Furthermore, it clarifies how the work is performed, representing the integration structure of an organization's units, providing structured information on the use of resources, the execution of tasks and the delivery of finished products to customers, without necessarily having a relationship with information technology systems (Minoli, 2008; Association of Business Process Management Professionals, 2013).

There are several notations and languages for process modeling, such as the extensions to UML (Unified Modeling Language), EPC (Event-driven Process Chain), and BPMN (Business Process Management Notation) (Association of Business Process Management Professionals, 2013).

BPMN refers to a series of standard icons for the design of processes, which facilitate a user's understanding by providing a set of builders that allow the creation of Business Process Diagrams, built through a basic set of builders (White & Miers, 2008). These symbols or icons are divided into five basic categories: Flow Objects, Data, Connecting Objects, Swimlanes, and Artifacts (Object Management Group, 2014).

2.3 BPMS Tools for Process Modeling and Simulation

In order to support the activities of mapping, modeling, simulation, execution and management of processes, not only are adequate methods and languages necessary, but also computational tools that automate these activities, such as BPMS (Business Process Management System) (Cheung & Hidders, 2011 ; Association of Business Process Management Professionals, 2013; Sebastian et al., 2014; Medoh & Telukdarie, 2017; Pereira & Freitas, 2019).

BPMS systems automate the BPM methodology enabling processes to be modeled, modified and improved with speed and control. Existing BPMS tools should be evaluated according to their characteristics and functionality, aiming to use the one that best adapts to an organization's conditions of use (Association of Business Process Management Professionals, 2013; Baldam, Valle and Rozenfeld, 2014).

There is a range of specific tools to support mapping, model generation, simulation and business process analysis, known as BPA (Business Process Analysis) tools. BPMS (Business Processes Management Systems) tools, in addition to offering support for process modeling and simulation, have functionalities aimed at the execution and management of processes. The analysis capacity of these latter tools is generally less in relation to the BPA tools, and some studies compare and research their integration (Blechar, 2008; Norton et al., 2010; Cheung & Hidders, 2011; Sebastian et al., 2014; Medoh & Telukdarie, 2017).

3 Research Method

The research in this study is classified as exploratory and qualitative in order to carry out a preliminary evaluation of the characteristics of a BPMS module, with the aim of using it in production management pedagogical scenarios. In this initial study, we chose to start with a simpler production system context and model. The steps were: (i) Definition of the simulation context and production layouts; (ii) Definition of the BPMS software for process simulation; (iii) Modeling the manufacturing scenarios and process (iv) Inputting data, such as product arrival time intervals, process activity times and machine data capacity (in this first test, we used the deterministic approach); (v) Execution of the simulation comparing and analyzing the output data; (vi) Evaluation of the BPMS as a possible tool to support teaching and learning of production management using the scenarios.

The simulation being considered relates to the manufacture of gears. However, in order not to dwell on technical issues in this article, this study considers a generic scenario with the production of 3 products (P1, P2 e P3), assuming different physical arrangements. Physical arrangements represent the positioning of transforming resources in an environment, determining how the raw material, transformed resources, information and customers will flow through operations. There are four main types of physical arrangements: positional, functional, cellular, and by product. This study simulates two different production configurations, associated with two different arrangements: functional (or process) layout and product layout. In the functional physical arrangement, each product flows differently within the environment, so that each one will perform a sequence necessary for their production, and the sequence may be different from the flow of the next product. With the product layout the physical arrangement is per product and the raw material follows a pre-established schedule showing which resources it will flow through.

4 Development and Results

In the simulated production scenario, the raw materials needed to manufacture the products arrive at the initial stock through an external supplier. The products P1, P2 and P3 go through 5 machines (A, B, C, D and E) for manufacturing activities. For the processes simulation, the manufacture of 300 batches of products is defined, with the arrival of instances at an interval of 300 minutes. The simulation time is defined as being 30 days, sufficient for the production of all batches. The product queue is managed through a concept known as FIFO (First In First Out).

In production processes, the capacities of productive resources such as product processing times (or lead-time) are the same for the two layouts developed, in order to be able to create comparisons between the results obtained at the end of each process, and analyze the effects of the different layouts on the production process. Then, in this work, the main difference is the ways of sharing machines, since characteristics such as transport time and of set up were not considered, due to the need for simplification in this preliminary simulation presented here. Processing times are shown in Table 1.

Table 1. Fictitious lead time of products for each machine

	Lead time for each machine (hours)		
Machines/Products	**P1**	**P2**	**P3**
Machine A	2	3	2,5
Machine B	4	2	2
Machine C	3	4	2
Machine D	3	2	5
Machine E	2	2,5	1

For the experiment, the Bizagi modeling and simulation module (Version 3.1) was used due to its ease of modeling (it supports BPMN notation) and the integrated way it can be used with the simulation, without the need for reworking with interfaces or the reintroduction of input information from the process model.

Using the software, the process model was built according to the scenarios described (illustrated by Figure 2) and then the parameters of time and types and number of machines for the simulation were inserted. In both layouts, the number of machines (types A, B, C, D e E) was defined as three of each type (Figure 3). To make an initial simplified analogy to physical arrangements, the two types of production layouts were associated with different machine distribution modes: machines dedicated to a specific product, in the case of the production line with product layout (Figure 2); and machines shared by all products in the case of the functional layout.

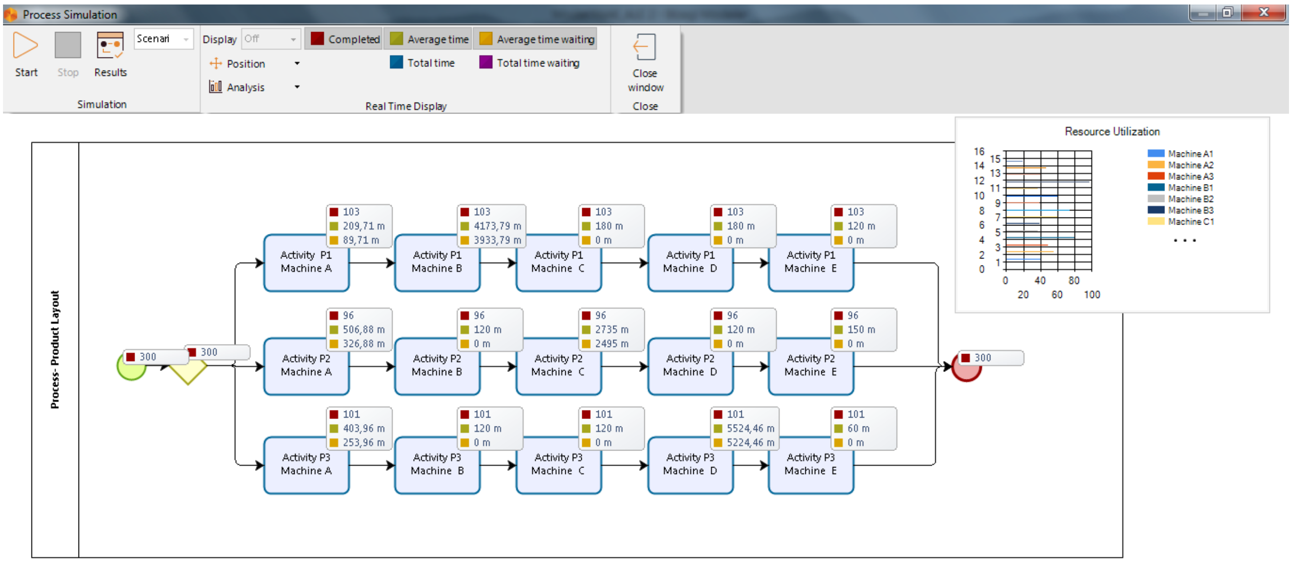


Figure 2. Manufacturing process model with product layout developed in Bizagi.

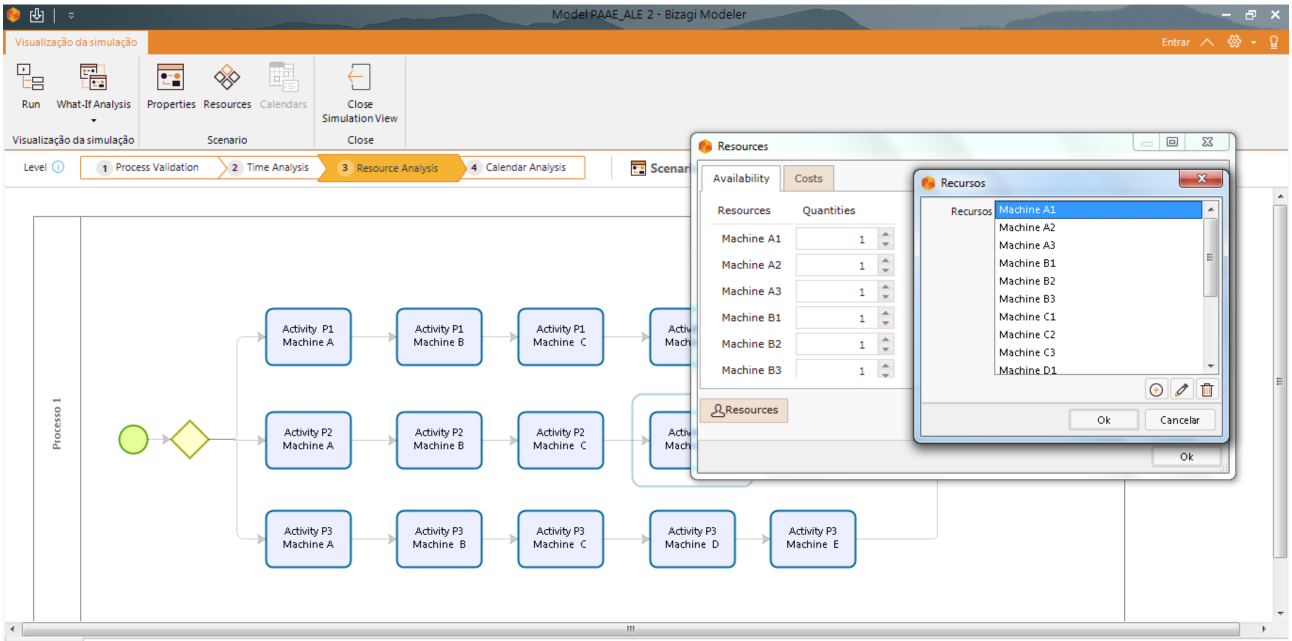
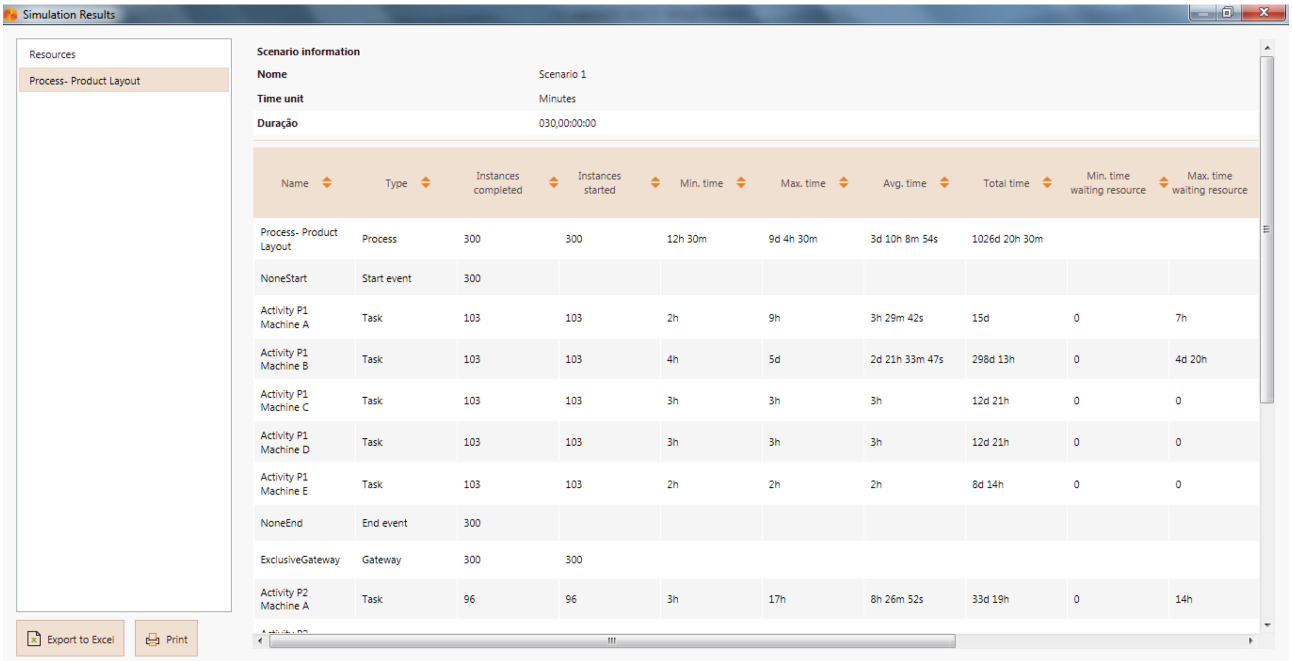


Figure 3. Data entry illustration related to resources in Bizagi.

Some of the difficulties in modeling and simulation are related to the consideration of manufacturing processes by batch; when exploring the use of the simulation functionalities of the system it was not possible to use batches of different sizes, such as, for example, a heat treatment process of gears, which in reality generally uses batch processing.

Also, due to these difficulties, the instance of input from the simulation was considered to be a whole batch of product (P1 or P2 or P3), and different times were defined for each product on each machine for these batch sizes. At first the simulation was programmed so that the proportion of products P1, P2 and P3 to be manufactured were equal to one third, with the final distribution being affected by the logic of the distribution of the software.

The results were analyzed both through graphical presentation and through reports (Figures 2 and 4). With these hypothetical scenarios, far from wanting to portray all the reality in this simply model, some effects can be perceived that help demonstrate a number of the concepts. For example, issues such as the best or worst load distribution among the machines and a shorter or longer time for the completion of the production of one or other type of layout can be identified.


Simulation Results

Resources
Process- Product Layout

Scenario information

Nome	Scenario 1
Time unit	Minutes
Duração	030,00:00:00

Name	Type	Instances completed	Instances started	Min. time	Max. time	Avg. time	Total time	Min. time waiting resource	Max. time waiting resource
Process- Product Layout	Process	300	300	12h 30m	9d 4h 30m	3d 10h 8m 54s	1026d 20h 30m		
NoneStart	Start event	300							
Activity P1 Machine A	Task	103	103	2h	9h	3h 29m 42s	15d	0	7h
Activity P1 Machine B	Task	103	103	4h	5d	2d 21h 33m 47s	298d 13h	0	4d 20h
Activity P1 Machine C	Task	103	103	3h	3h	3h	12d 21h	0	0
Activity P1 Machine D	Task	103	103	3h	3h	3h	12d 21h	0	0
Activity P1 Machine E	Task	103	103	2h	2h	2h	8d 14h	0	0
NoneEnd	End event	300							
ExclusiveGateway	Gateway	300	300						
Activity P2 Machine A	Task	96	96	3h	17h	8h 26m 52s	33d 19h	0	14h

Export to Excel
Print

Figure 4. Example of a simulation report in Bizagi.

5 Conclusions

Modeling, simulation and business process management (BPM) techniques are important tools for the design and management of production systems, and the teaching/learning in conjunction with typical production management scenarios can provide greater motivation for students and a better understanding of the subjects covered, when compared to classes based purely on theoretical models and not associated with real situations or life-like situations. This study carried out a preliminary evaluation of a BPMS module with the simulation of processes aimed at the future teaching/learning of undergraduate students of Production Engineering courses for the assimilation of the BPM and Production Management content through life-like examples. Specifically, two different production configurations were simulated and analyzed, associated with two different layouts: functional and product arrangement.

It was discovered that using a version of the Bizagi module for the modeling and simulation of different production layouts clearly facilitated the modeling processes, as well as demonstrating greater agility for the data entry simulation of these processes. However, in this first exploratory research of the simulation functionalities in the system, there were some difficulties, such as the consideration of batch manufacturing processes (mainly the use of batches of varying sizes), which limit the use of this simulation module for teaching/learning of Production Management concepts involving different physical arrangements of machines.

Part of the difficulties may be due to the authors' inexperience with the system. Therefore, further investigation is considered necessary for conclusions on the adequacy of teaching and learning of BPM and themes related to Production Management with this or new versions of BPMS from the market to be fully understood.

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Development Process of a Rubric for Assessment of Leadership Competences in Project Management Scenarios

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Abstract

In the field of Project Management, leadership competences have a significant impact on project execution, and are identified as a key factor in the success of an organization. In this regard, defining strategies and tools for development and assessment of leadership competences is a significant contribution to project management research and practice. Scenario-based learning is an interesting approach for development of a wide range of competences because it involves real problems and allows practitioners to face challenges based on their own professional experience. For the assessment process it is possible to identify indicators related to the competences to each scenario. The success of this process is influenced by the instrument that is being used and rubrics are one of the instruments that may be used for competence assessment. A rubric includes criteria and standards considering a specific scale on which different levels of assessment are established. This paper aims to describe the process of creating and validating a rubric, designed to assess leadership competences in project management scenarios, considering the Individual Competency Baseline (ICB). To illustrate this design and validation process, only one criteria of the rubric will be presented. The design of the rubric includes five phases, and includes internal validation based on an expert agreement, considering content, construct and criteria validation of the rubric. The expected outcomes of this work are the presentation of the results of the internal validation process that was conducted by two experts. As future work, the final version of the rubric will be developed as a contribution to assess leadership competences in project management scenarios.

Keywords: Rubrics; Scenarios; Project Management; Leadership Competence; Competences Assessment; Engineering Education.

1 Introduction

Project management is a globally recognized profession (PMI, 2017) in which guides and standards are used to describe tools, techniques and concepts that support the development of effective project management processes (Chen & Partington, 2006). The International Project Management Association (2015) is a global project management organization that, through the Individual Competence Baseline (ICB), defines the competences required by professionals in project, program, and portfolio management. Among the 29 competences mentioned, in three categories, it is possible to highlight the leadership competence for their importance to the success of projects. The ICB is a global standard widely used to certify, develop and assess professional competences (IPMA, 2015).

In general, competence assessment is the process that measures the capabilities of individuals in both professional and academic settings (Succar et al., 2013). Rubrics are indicated as one the tools that can be used in the assessment process (Ana et al., 2020), and it is very common in the educational area to assess performance and facilitate student learning (Reddy, 2010). However, rubrics can be used in other assessment contexts, for example, projects and programs (Dickinson & Adams, 2017).

The use of rubrics, and its development is an important approach to mitigate the subjectivity within the assessment processes (Reddy, 2010). It is important to note that when the rubric provides information that does not match with the assessment objective and what it is intended to assess, then it will be invalid (Russell & Airasian, 2012). In this sense, the rubric validation step is important in order to identify and estimate if there is the bias and distortion of the instrument (Reddy, 2010).

Considering the lack of studies on the development and validation of rubrics for the context of project management, and also considering the importance of leadership in this context, the aim of this article is to describe the process of creation and internal validation of a rubric, designed to assess leadership competences in project management scenarios.

The article is organized in six sections, the first section introduces and establishes the objective of the research, the second section presents a brief contextualization about the main concepts surrounding the theme of the study, the third section describes the methodology used in the process of development and internal validation of the rubric, the fourth section highlights how the process described in section three occurred, and finally the last section deals with the conclusions of the study. This is an ongoing project and for that reason only a part of the process will be described.

2 Background

Traditionally, project management is understood as the application of knowledge, skills, tools, and techniques to project activities to satisfy project requirements and enable project execution effectively and efficiently (PMI, 2017). Project managers' skills are correlated with job performance and can be improved through training or other development activities (González-Marcos et al., 2016). In practical terms, they can be defined as the ability to apply knowledge, skills, and abilities to various situations, in order to achieve the expected result with the project (IPMA, 2015; Črešnar & Nedelko, 2019). For a better understanding, the International Project Management Association (2015) proposes three dimensions about what a competence must to include:

1. Knowledge: is the body of information and experience that an individual possesses.
2. Skills: are the specific techniques that an individual knows that enable him to perform a task.
3. Ability: is the effective use of knowledge and skills in a given context.

In this sense, the International Association for Project Management (IPMA) defined through the study of Individual Competence Baseline (ICB, 2015) a specific set of competences (twenty-nine) for individuals working in the area of Project Management. The individual should have perspective competences that respond to the context of projects, personal competences that respond to personal topics, and project competences that respond to specific project management practices. The wide range of competences is divided into the three (3) dimensions:

Practice Competences (13): Project design, requirements and objectives, scope, time, organization and information, quality, finance, resources, procurement, plan and control, risk and opportunity, stakeholders and change and transformation.

People Competences (10): Self-reflection and self-management, personal integrity and reliability, personal communication, relationships and engagement, leadership, teamwork, conflict and crisis, resourcefulness, negotiation and results orientation.

Perspective Competences (5): Strategy, governance, structures and processes, compliance, standards and regulation, power and interest and culture and values.

According to Falaki (2020), leadership competences associated with personal competences, should be recognized as the core of project management. Several studies highlight the importance to create effective leadership, taking into account the competences and personal characteristics of the leader (Falaki, 2020). The leadership role of the project manager involves taking risks and initiatives in order to achieve the organizational goals and to ensure the sustainability of business (Latif et al., 2020). According to the Project Management Institute (PMI), organizations are looking for managers with additional leadership competences due to the complexity and competitiveness of the market (PMI, 2017).

In this sense, leadership competences are identified as a key factor in the success of an organization (Podgórska & Pichlak, 2019; Chatzglou et al., 2017). There is also an understanding of the significant impact of managers' performance for the project success, considering the expected competences, especially in terms of leadership

(Alvarenga et al., 2019). Leadership competences are necessary in the project manager role and practice, and are defined as "knowledge, skills, and behaviors needed to guide, motivate, and direct a team to help an organization achieve its organizational goals" (PMI, 2017).

ICB (2015) highlights the knowledge, skills, and abilities required for developing leadership competence as evidenced in Table 1 (IPMA, 2015).

Table 1. Knowledge, Skills and Abilities of the Leadership Competences

Knowledge	Skills and abilities
▪ Leadership models; ▪ Individual learning; ▪ Communication techniques; ▪ Coaching; ▪ Sense-making and sense-giving ▪ Bases of power; ▪ Decision taking (consensus, democracy/majority, compromise, authority, etc.)	▪ Personal self-awareness; ▪ Listening skills; ▪ Emotional strength; ▪ Capacity to express a set of values; ▪ Dealing with mistakes and failures; ▪ Sharing values; ▪ Creating team spirit; ▪ Methods and techniques for communication and leadership; ▪ Management of virtual teams.

Competence development is a fundamental need, but one that is designed by an individual pathway, where individuals are motivated and engaged in developing competences to improve their job performance and career opportunities. There is no one path to developing competences, but is a process that involves interaction between activities and project contexts (IPMA, 2015) and is carried out over the years with experience (Hermarij, 2013). There are different ways to measure competences in project management, these include psychometric instruments, project management knowledge testing, peer assessment, and assessment centers (González-Marcos et al., 2016). Fanelli et al. (2017) states that competence assessment is a key management strategy, which can produce valid results in terms of job motivation and quality in the work environment.

The competence assessment process is as complex as it is useful, and its complexity starts from the need to define precisely what is going to be assessed (Fanelli et al., 2017), it is also not so simple to design reliable and valid tools that make the process possible (Mathieu et al., 2011). There are three main decisions to be made in the assessment: what to assess, how to assess, and who assesses. In this sense, it is necessary to use methods to identify the knowledge and skills required by each competence, as well as to select the approach used in the assessment, according to the context. Furthermore, it is essential to clarify why the competence need to be assessed - *why* (Mathieu et al., 2011).

Rubrics can be used in the assessment process as a support tool (Ana et al., 2020). Are defined as "a type of matrix that provides scaled achievement or comprehension levels for a set of quality criteria or dimensions for a particular type of performance, for example, a paper, an oral presentation, or use of teamwork skills" (Allen & Tanner, 2006, p. 197). They can also be characterized by descriptive scoring schemes developed by raters to provide guidance for analyzing product or process performance (Brookhart, 1999; Moskal, 2000). According to the educational literature is used as a tool to describe and rank observable qualitative differences in performance analysis (Reddy, 2010).

From this perspective, the rubric provides a clear assessment structure for observation, describing in detail the performances to be assessed (Ana et al., 2020). This minimizes the discrepancies between raters (Melguizo-Moreno & Gallego-Ortega, 2020). Using rubrics in assessment processes makes it possible to communicate objectives with the stakeholders, highlighting what is expected and what behaviors are expected in different performance levels (Dickinson & Adams, 2017). According to Panadero & Jonsson (2020) they can be designed and implemented according to the intended use in the assessment, and there is no ideal rubric. However, there are general recommendations in the literature for their design and implementation.

Rubrics to be robust must be unbiased and free of distortion. For that reason, one of the steps of designing a rubric is the validation process. Validation represents the degree of accuracy that the assessment instrument measures what is intended (Reddy, 2010). According to Moskal & Leydens (2000) validation is traditionally subdivided into three categories: content validity, construct validity and criteria validity. Content-related validation is concerned with how well the instrument collects appropriate criteria/samples from the content domain (Moskal & Leydens, 2000). This validation includes any validity strategy that focuses on gauging content, in order to verify the degree to which the instrument is a representative test of the content for the purpose or specification it was initially designed for (Brown, 2000). For example, a history exam in which the questions use complex sentence structures may unintentionally measure students' reading comprehension skills rather than their knowledge of history. A teacher who is interpreting a student's incorrect answer may conclude that the student does not have the appropriate history knowledge when, in fact, that student does not understand the questions. The teacher has misinterpreted the evidence - making the interpretation invalid (Moskal & Leydens, 2000).

To understand construct validity, one must understand what a construct is (Brown,2000). The construct relates to psychological construct processes that are internal to the individual, such as reasoning and creativity, Thus, if a scoring rubric is used to guide the assessment of these aspects then it should highlight criteria that address these processes (Moskal & Leydens, 2000).

Criteria-related validation checks whether the identified criteria supporting the assessment results correlate to a current or future fact. For example, when assessing individuals through simulated work environment experiences, the quality of the rubric takes into account if the assessment criteria address the components of the activity and if it is directly related to practice in the work environment. If the assessed receives high scores, it is suggested that he (assessed) will perform highly in the future work environment (Moskal & Leydens, 2000). Moskal & Leydens (2000) states that being aware of the types of validation evidence for a rubric throughout the development process, improves the adequacy of the interpretation of such a rubric when used. Therefore, it is very important to be aware that before the development of the instrument it is important to design the validation process, in order to design a consistent and effective rubric, in addition, a list of questions can be useful when assessing of a given rubric against its stated purpose.

3 Methodology

The objective of this study is to describe the process of creation and internal validation of a rubric, designed to assess leadership competences in project management scenarios.

In this study, we intend to assess the leadership competence, included in the people competences. The process of developing the rubric was designed in 5 phases based on studies by Reddy (2010); Moskal & Leydens (2000) and Melguizo-Moreno & Gallego-Ortega (2020). The first phase of the study refers to the definition of the competence to be evaluated, based on the International Project Management Association (IPMA) through the study of Individual Competence Baseline for Project, Program and Portfolio Management (ICB, 2015). In the second phase focused on the identification of the assessment criteria, considering the references for the development and construction of the criteria. This phase was inspired by Hermarij (2016) and the study of Individual Competence Baseline for Project, Program and Portfolio Management (ICB, 2015). In the third phase the development of the rating scale of the assessed criteria was developed, based on a five point scale: inadequate, lower than expected, reasonable, good, and excellent. The fourth phase, aimed at the design of the development of the rubric, and finally, the internal validation (fifth phase).

It is worth mentioning, that due to the temporality of the study (under development) the external validation process was not carried out, such process relies on the judgments of experts outside the present study to verify if the results found are pertinent to other points of view. On the other hand, the internal validation relies on the inputs from two experts and three dimensions were considered, namely: content, construct, and criteria.
In order to characterize the experts, we have Expert A is a professor and researcher with more than 20 years of experience in the academic world, with high-impact publications, projects and cooperation with universities and companies. Expert B a professor and researcher, whose research focuses on Competence-Based Curriculum, Leadership and School Organization.

Thus, this process starts from the reflection on the adequacy of the item regarding its relevance and representativeness. The reflections were based on the validation evidence suggested by Moskal and Leydens (2000) and considered the following questions:
With respect to the content validation process, three (3) questions were considered:

1. Do the assessment criteria address any extraneous content?
2. Do the assessment criteria for the scoring rubric address all aspects of the intended content?
3. Is there any content addressed in the task that should be assessed through the rubric, but is not?

Regarding the construct validation process, two (2) questions were considered:

4. Are all important indicators of the intended construct assessmented using the scoring scales?
5. Are any of the scoring criteria irrelevant to the construct of interest?

Finally, for the criteria validation process, four (4) questions were considered:

6. Are the indicators consistent with the criteria (communication) presented?
7. Can the indicators inherent to the criteria (communication) be assessed using the assessment instrument?
8. Does the criteria (communication) assess performance indicators related to professional practice?
9. Are there indicators that are not represented in the scoring scales?

Accordingly, a list of nine (9) questions was sent via email individually to each expert for further analysis of the results.

4 Design, Development and Internal Validation of a Rubric

Based on the literature review the rubric was designed, developed and partially validated. The steps of the developing and validating the rubric to assess leadership competences in project management scenarios will be discussed in this section. Initially, the results of the rubric design will be presented following the validation process.

4.1 The rubric design

The design process of the rubric follows 5 phases, namely:

(1) Definition of the competence to be assessed

(2) Identification of the assessment criteria

(3) Development of the rating scale of the assessed criteria

(4) Design of the rubric

(5) Internal validation of the rubric

In this study, the definition of competence to be assessed (phase 1), will be based on the International Project Management Association (IPMA) through the study of Individual Competence Baseline for Project, Program and Portfolio Management (ICB, 2015). Thus, the definition of leadership competences considered in this study is:

> "Providing direction and guidance to individuals and groups. It involves the ability to choose and apply appropriate style of management in different situations. Besides displaying leadership with his or her team, the individual needs to be seen as a leader in representing the project to senior management and other interested parties". (IPMA, 2015, p. 333).

Regarding the identification of the criteria for the development of the rubric (phase 2), the work developed by Hermarij (2016) and the study of Individual Competence Baseline for Project, Program and Portfolio Management (ICB, 2015) inspired the development and construction of the assessed criteria. The criteria of responsibility, demonstration of commitment, team/individual orientation and direction are some of the examples of criteria included in the rubric. In this sense, we sought to use assessment criteria in a general way so that they can be applicable in different contexts (scenarios) for assessing leadership competences.

Phase 3, the development of the scale for the assessment criteria, was initially carried out considering the identification of levels of performance, in order to portray the assessment in a complete and comprehensive way. The most important aspect of the performance levels is the description of the quality of the performance that will be assessed. A second aspect of performance levels that was considered is how many levels the rubric should have. In this study, five point scale was considered: bad, beginner, intermediate, advanced and expert.

Once the number of levels was decided, a description of the expected performance for each level and criteria was developed. To do this, the setup used was to start describing the highest performing level, in this case, expert, then develop to the other levels in a descending order. Finally, a separate score was developed for each performance level.

Thus, the design of the rubric (phase 4) to assess leadership competences in Project Management contexts was initially conceived, with 7 criteria and 5 performance levels (scale). Finally, the purpose of this study comprises the internal validation of the rubric (phase 5) and will be described in the next section.

4.2 The Validation Process

In section three (3), we described which aspects according to Moskal and Leydens (2000) are used as evidence of rubric validation.

To illustrate the internal validation process, one criteria of the rubric, namely communication. The process of this process was developed using nine questions as a guide for this process, based on three dimensions: content validation, construct, and criteria.

The experts' suggestions regarding the content validation process states that the assessment criteria do not address extraneous content, however, it was evidenced that such criteria partially consider aspects of the intended content. Furthermore, there is no content that should be assessed by the rubric, but is not.

About the construct validation process, according to the experts, what was designed to be assessed is being represented in the assessment instrument. All important indicators of the intended construct are assessed, and no assessment criteria are irrelevant to the construct.

Finally, regarding the criteria validation process, the experts showed that the indicators are consistent, are considered on all the scoring scales, and are able to assess performances related to professional practice. They can also be assessed using the assessment instrument, although this then depends on the applicable context (scenario).

In addition, the experts suggested improving the performance description for all levels, and changing the levels to: Inadequate, Lower than expected, Reasonable, Good, Excellent. The results of the validation process are shown in Table 2.

Table 2. Communication Criteria

Criteria	Inadequate (0)	Lower than expected (1)	Reasonable (2)	Good (3)	Excellent (4)
Communication	Communication is not adequate, in that ideas are presented in a disorganized and diffuse way. It does not demonstrate any level of argumentation. The objectives are not explicit and clear.	Communication is below expectations, in that ideas are presented in a disorganized and incoherent way. It demonstrates a weak and incoherent argumentation. The objectives may not be explicit and clear, due to the difficulty in interpreting the discourse.	The communication is reasonable, in that the ideas are, in general, presented in a partially organized way. It shows an effort in the argumentation, although still incoherent. The objectives can be partially explicit and clear.	Communication is good, in that ideas are, in general, presented in an organized way. It demonstrates a coherent argumentation. Objectives are explicit and clear, with little room for misinterpretation.	Communication is excellent, in that ideas are presented in an organized and consistent manner. It demonstrates a coherent and reasoned argumentation. The objectives are explicit and clear, and are understood by the interlocutor.

5 Conclusion

The importance of assessing the competences of professionals working in Project Management is undeniable. Assessing the competences focused on leadership, through scenarios, becomes an excellent way to prepare professionals effectively for their practice.

Some of the main results of the study presented indicate that the rubric developed, according to the experts, the content is adequate for the purpose. However, it was evidenced that it partially considers aspects of the intended content. In relation to the construct validity issues of the rubric for the communication criteria there is consistency, and in relation to the validation of the criteria (communication) it is shown to be valid. Furthermore, the Individual Competency Baseline Reddy (2010), Moskal & Leydens (2000), and Melguizo-Moreno & Gallego-Ortega (2020) were the main reference bases to support, structure, and guide the internal validation of the rubric.

Finally, it is concluded that the development of rubrics allows the reproduction for other competences of Project Management, and can serve as support tools and help to develop reliable and valid methods in the assessment of competences. It is important to note that in this initial study, the reliability of the rubric was not discussed, so this study is still in progress.

Based on this first validation, it is possible to review all criteria and content, in order to present the final version of the rubric to be implemented in the scenarios-based learning. As future work, it is expected to improve reliability by external validation with experts.

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Risk Assessment of Project Based Learning Failure via Bayesian Belief Networks and Analytical Hierarchy Process – A Literature Review

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Abstract

Project-based learning has been used in engineering education because of its expected effectiveness in developing students' professional knowledge. With a growing number of Project-based learning research and practices in engineering education, a systematic review was conducted regarding the use of Project based learning and risks of failure. It has been noticed that risks in the implementation using Bayesian Belief Networks and Analytical Hierarchy Process have not been addressed in the current reviewed literature, and even less attention has been paid to risk responses. The aim of the study is the identification of the risks on the use of the Project-Based Learning Method on the teaching of Operations Management disciplines to engineers and propose a method to combine the risks by using Bayesian Belief Networks and Analytical Hierarchy Process to establish prioritization for responses. The author conducted an in-depth literature review of Journals indexed in Scientific Databases, such as Google Scholar, Scielo, Scopus, Web of Knowledge, and Journals related to engineering education listed in JCR Journal Citation Reports. Based on the information obtained from the researched literature, respective actions are recommended to improve the method currently used to attain operational excellence in the teaching of Operational Management. Recommendations on future research directions for engineering education researchers are proposed to optimize Project-based learning curriculum design.

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 that arise during the implementation phase and often return to traditional teaching methods (Henderson, 2012). Therefore, it is important to identify, describe and deal with risk factors that have a direct impact on PBL's.

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. 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.

The objective is to propose a method for risk assessment via Bayesian Belief Networks (BBN) and Analytical Hierarchy Process (AHP), to identify the risks and responses to ensure successful PBL's are conducted in collaboration with local companies. If the operational structure is not defined, risks are not identified, and the proper responses are not provided, PBL can fail. T

his study assesses the risks and completes a gap in the literature by assessing the risk factors on the use of the Project-Based Learning Method on the teaching of Operations Management to engineers. The diversity of risk factors presented here highlight 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, students and increase the quality of PBL as well as universities sustainability. It is noteworthy here that the study focus is on Project Based Learning that involves companies. Successful PBL's in this case will result in a significant reduction of business risks and achievement of excellence in quality and organizational safety by supporting local companies to attain the following goals: 1 - Seeking creative, strategic directions to monitor the changes in the economy, market, and technologies to achieve operational excellence; 2 - Studying modern trends in the use of risk analysis tools aimed at improving product quality and safety; 3 - Studying modern and automated (digital) processes for optimization of organizational strategies to improve results and reduce costs; 4 - Seeking technologies to ensure maximum efficiency and meeting specific market needs; 5 - Seeking ways to add value to products and services through continuous improvement of products and services to retain customers and sustainability wingers.

None of the studies present herein dealt with risk assessment and its impacts on PBL. The literature research revealed that most previous studies addressed PBL and challenges without giving a methodology for risk prioritization using Bayesian Belief Networks and AHP (Analytical Hierarchy Process in PBL. The paper provides responses to the following research questions: 1 – What are the most significant risk factors for using PBL in engineering courses? 2 – What are the risks when trying the application of the method to support the operations management of companies? 3 – How to combine the risks by using BBN and AHP to establish prioritization for responses? In sections 3, 4, and 5, several papers are cited, and none of the studies present herein dealt with risk assessment of PBL using BBN and AHP. This paper is divided into five sections; the first introduces the concepts of the study, the second describes PBL, Section 3 the challenges and Risk Assessment of PBL Failure. Section 4 presents BBN (Bayesian Belief Network), section 5 deals with AHP (Analytical Hierarchy Process), Section 6 describes Methodology, section 7 results, and section 8 conclusion.

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 the description of the experience of using PBL methodology in Materials Science courses, conducted by four different Spanish universities on different engineering degrees. The author analysed and evaluated how the PBL was perceived by the students and the lecturers that took part 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 own topic, identify, and explain what the topic is, why they choose that, and how they solve the problem. Thevathayan (2018) presented an experience evolving a hybrid-teaching model by using the action research cycle plan-act-observe-reflect over 3 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 obtained indicated that PBL was effective in enhancing the learning experience in the instructional scenario studied. Schneider (2020) used PBL as a means of enhancing student engagement. The activities of the partnership focused on the co-design and enactment of and co-reflection on PBL units. 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 for sustainability by using a PBL methodology. This framework aims to inspire curriculum design for sustainability education and analyse the implementation of PBL in each cultural context. Palmer and W. Hall (2011) presented the result of PBL offering in engineering PBL at Griffith University in Australia. The author observed that students generally enjoyed the experience. The aspects needing improvement were listed and documented. García-Martín and E.Pérez (2017) presented a method to guide teachers in 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 used to 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 survey of Henderson et al. (2012) mentioned that faculty are aware of student-centered teaching methods but find it challenging to deal with unexpected issues that arise during the implementation phase and thus 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. According to the author, the complete infrastructure is not defined, probably due to the lack of 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 about implementation and execution of PBL are both theoretical and practical. Theoretically, debates remain over the best approach to incorporate PBL and the extent of 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 so they can 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 largest 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). And teachers, too, often find it difficult to adjust to PBL (Prince & Felder, 2006; Thomas, 2000). Furthermore, institutional difficulties include resources, program sustainability, scalability, physical facilities, and management (Bielefeldt et al., 2009)

3 BBN (Bayesian Belief Network)

BBN has been widely used in the industry to estimate risks. Bayesian-based reliability was used to estimate the corrosion (Yang et al., 2016). Bayesian network (BN) was 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). BNs, also known as BBN's, are a causal structure used by probability risk analysis specialists to obtain information about basic risk events and the necessary interventions to address risks (Rechenthin, 2004; Mosleh, 1992). The use of BNs in fields related to safety, maintenance, and reliability has been increasing quickly (Mahadevan, 2001). Bayesian methods have been used comprehensively in many applications and provide a structure for addressing the limitations of human reliability analysis (Podofillini 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 manufacturing or servicing of rotors. The objective of BN methodology is to allow more straightforward predictions of risk events; it is a structure representing arguments when uncertainty exists. The nodes represent the variables, and the arcs the direct dependency between those.

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 difficult 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 stacking process. 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 "aij"(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). (Mls and Otcenaskova, 2013).

5 Methodology

To achieve the proposed objective and respond to the research questions, an in-depth literature review of Journals indexed in Scientific Databases, such as Google Scholar, Scielo, Scopus, and Web of Knowledge, identified the risk factors on the use of PBL. 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, 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 with relevance 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 Design of PBL and challenges/risk assessment of PBL failure were disregarded. A list of risk factors found in the researched literature 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. For further study, it is recommended to create a survey in Google forms to obtain the probability for the risk factors from Students, Professors, and Organization Leaders. The probabilities for each risk factor obtained should be combined with BBN (Bayesian Belief Networks) to get the probabilities for the risk categories. AHP (Analytical Hierarchy Process) should then be used to find the impact for the risk categories. The last step would be implementing risk responses to address the risk categories as required by their RPN (Risk Priority Number).

6 Results

The quality tools Process Map and Relationship Digraph were used to identify and classify the risk factors; a traditional PBL Process Map was prepared to determine the risks when trying to apply the PBL projects in universities to support the operations management of companies in the region. The flowchart of Figure 1. shows the structure generally practiced in the conduction of PBL projects and the risks presented in each step. The letters in red represent the learning principles (category) of risks: C: Cognitive Learning Failure, S: Social Learning Failure, and T: Theory and Practice Learning.

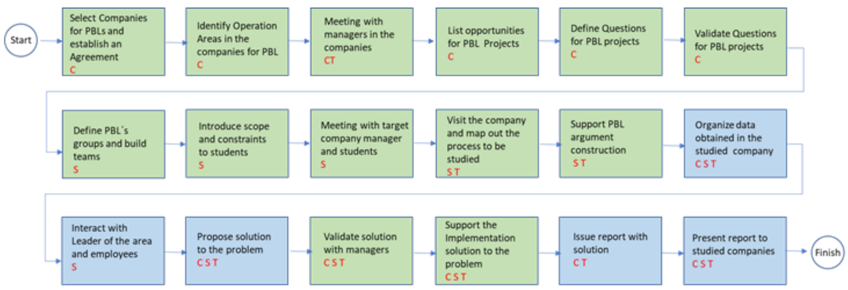

Figure 1. structure generally practiced in conduction of PBL projects and risks.

The risk factors impacting PBL failure were identified in the researched literature. The risk factors were clustered into categories to establish the cause-and-effect relationship to the failure of PBL. Affinity Diagram was used to organize the risk factors within 3 learning principles and 9 categories, as suggested by Xiangyun (2013). 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
	CC: Wrong Choice of Project	C7	Project complexity incompatible with time and resources
		C8	The project not related to discipline
		C9	Workload too heavy for the student
		C10	The low ability of students (slow learner)
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 industrial process

Based on Table 1, BBN was prepared, logical connective OR is utilised since risk factors are independent. The diagram in Figure 2 shows the BBN combining all risk factors in the different learning principles categories.

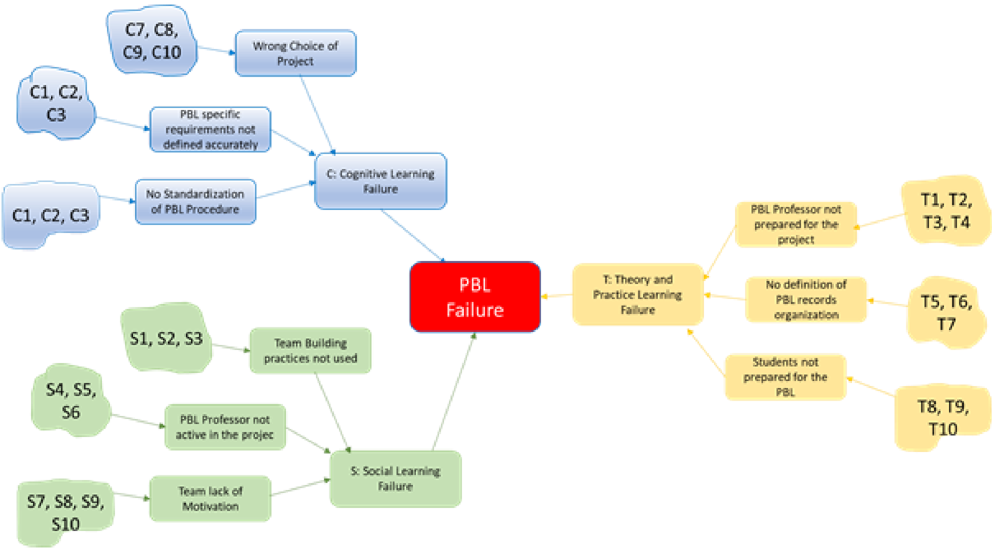

Figure 2. BBN combining all risk factors

When applying the model in future studies probabilities for each risk factor needs to be elicited from students and professors. The probability values are then loaded into a BBN software and by sensitive analysis the probabilities of each risk category can be obtained.

To obtain the impact for each risk category the AHP needs to be utilized. Pairwise comparative matrices should be prepared as shown in Table 2. An interview process needs to be conducted to obtain from professors and students the degree of impact of each risk on the failure of PBL. As an example, the following question need to be made: Considering that PBL fails, what is the importance of one category (example: CA), relative to the other (example: CB) in causing the failure? In this case suppose the score 7 is attributed based on Table 3, so a12=7. This means that element CA has a very strong importance relative to element CB. For symmetry, it is assumed that if a12 = 7, then a21 = 1/7. The relative importance for all other risks is estimated in a similar way and translated into the numerical pairwise comparison matrix shown in Table 2. Based on the completed pairwise comparative matrix, the weight values (impact) of risks can be quantitatively calculated using the eigenvector corresponding to the maximum eigenvalue of pairwise comparative matrices as the weighted values. Table 5 is used to obtain the probability and Impact Score for all risk categories.

Table 2. Risk Factors impacting PBL failure.

	CA	CB	CC	SA	SB	SC	TA	TB	TC	**Weight**
CA	1	7								
CB	1/7	1								
CC			1							
SA				1						
SB					1					
SC						1				
TA							1			
TB								1		
TC									1	

Table 3. Risk Factors impacting PBL failure

Saaty scale	Definition
1	Equal importance
3	Medium importance
5	High importance
7	Very high importance
9	Extreme importance

The global risk score and class need to be determined using the risk scoring matrix shown in Figure 3 (Hyun et al., 2015). As an example, the final risk score for the risk category CA is obtained in the following way: Considering the probability for CA is 0.6 and the impact 0.17, based on Table 4 the probability rating score is (value: 4) and the impact rating score is (value: 5) for the risk CA. To obtain the final risk score for CA Figure 3 is referenced, in this case the final score is (value: 20).

Table 4. 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 risk scoring matrix in Figure 3 combines the probability and impact score for each risk and provides the final risk score

			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 3. risk scoring matrix

For further study, the quantitative values for probabilities and impact step could be obtained by administrating a Survey in Google Forms to students, professors, and Partner. As explained before, the next step is to consolidate all the probabilities obtained with the survey using BBN to obtain the probability of each category of risk. The risk categories can then be evaluated by a pairwise comparison to define the weights of each category. The Combination of Bayesian Belief Networks results with Analytical Hierarchy Process results will determine the final score for the risks and the required prioritization for risk responses.

7 Conclusion

As proposed in the introduction, the study demonstrated that AHP in conjunction with BBN can 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 key 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 sustainability of the universities. In this regard, 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 PBLs process can influence the decision of professors and university engineering school coordinators. The application of this innovative risk assessment method in the PBL process fills a gap in the literature since no previous work dealt with this specific subject.

As expected, the contribution is significant since risk assessment in the PBL process permits decision-makers to assign funds for critical activities that can impact universities' sustainability. 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 on the use of PBL at engineering courses?"* a table with the risk and risk categories is presented. In response to the second question, "*2 – What are the risks when trying the application of the method to support the operations managements of companies?"* a table with the risk and risk categories is presented. In response to the third question, *"3 – How the risks could be combined by using BBN and AHP to establish prioritization for responses?"* a method is proposed that allows the combination of risk factors by using BBN and AHP and this demonstration should be done in future studies. 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.

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Influence of Improvisation Education to Teamwork Abilities Based on Competency

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Abstract

With the complexity of society, it is changing into where sudden and irregular problems are becoming more frequent. In the society based on this uncertainty, it is important to demonstrate teamwork that can be flexible and appropriate to respond to unexpected problems. Furthermore, the society is becoming diverse nowadays, and teams frequently include members from many different countries, fields, and cultures. To carry out projects in this society, it is necessary to understand the characteristics and preferences of the individuals who belong to the team to perform well under unexpected circumstances. This paper focused on the change in performance of each participant before and after Oh My God Experience (OMG), which is an improvisation education throughout the Cross-cultural Engineering Project (CEP) based on global Project-Based Learning (gPBL). Each participant of the CEP at SIT in 2019 and KMUTT in 2020 answered a questionnaire on how the individual ability (Team-oriented, Backup, Monitoring and Leadership) affects the performance in the team. Furthermore, the competency of the participants was measured by Progress Report On Generic skills (PROG) after the CEP. The results of the questionnaire were compared with the results of the PROG to analyze the correlation between them. The result showed that participants who answered that the team-oriented skills were important or difficult before and after the OMG scored higher on the PROG with a significant difference in "Attunement" and "Harmony" than those who answered that they were not. This suggests that they found them difficult during the OMG because they were aware of them, and that they are in the stage of conscious maturation. Alternatively, the participants who answered that it was important or difficult before and after the OMG scored lower on the PROG with a significant difference in “Autonomy” than those who answered otherwise. This may be because they are in the stage of unconscious maturation and are not aware that they are important or difficult.

Keywords: Teamwork Competency, Improvisation Education, Project-based Learning, Multinational Team

1 Introduction

1.1 Background

In recent years, unpredictable problems and rapid changes are frequently occurring in society due to digitalization, globalization, and diversification. This environment is called VUCA, a term coined from Volatility, Uncertainty, Complexity, and Ambiguity. In this VUCA society, unanticipated problems frequently arise in the course of work (Petrie Nick, 2011). Therefore, leaders need to be cooperative with their teams and have good communication (Lawrence, 2013). In projects, it is important for teams to be flexible to change and recognize opportunities to improve their deliverables to produce the best results under time and cost constraints. Under these constraints, teamwork becomes critical. It is difficult to achieve high performance as a team if the team only focuses on individual tasks, but if the team is aware of teamwork, the team can achieve high performance, leading to better deliverables (Aikawa, 2012) to strengthen the individual teamwork skills of team members, educational institutions need to provide educational methods using active learning. In recent years, universities have been using Problem-Based Learning (PBL), an educational method that provides students with an environment to work in teams to solve problems that exist in modern society. PBL is an educational method that provides students with the benefits of collaboration, from which they learn the importance of teamwork. In this paper, PBL is defined as a project in which a team of international members from multiple nationalities and cultures works together to solve a problem.

1.2 Expectation from conducting improvisation education

One of the active learning methods, called improvised education, has been gaining attention in recent years. This strengthens the ability to solve problems, be creative, and build relationships among members through group work. Improvisation has long been practiced in the fields of music and theater, but in recent years, it has been incorporated into education as an active learning program in many academic fields, as its improvisation and creativity are also required in business situations. In recent years, however, improvisation and creativity have been incorporated into education as active learning programs in many universities, as they are required in business situations as well (Alves & Leão, 2015; Guerra et al., 2017; Jollands et al., 2012). For example, students improvise and dance to background music that changes one after another, such as hip-hop and African drumming, or simulate peacekeeping in Bosnia over a three-day period. The effects of this improvisational education include a more positive attitude toward sudden changes, improved teamwork, quicker decision making, and smoother project management. At Shibaura Institute of Technology, we are conducting a Cross-cultural Engineering Project based on PBL (Kongwat et al., 2020; Navas, 2017, 2018). In this context, we are implementing an improvisational education called OMG (Oh My God). Figure 1 shows the events and specific implementation schedule during the CEP.

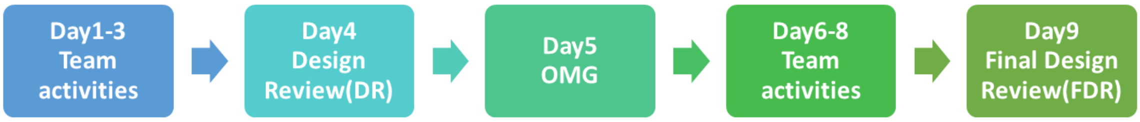


Figure1. Activity schedule in the CEP

1.3 Research question and objective

There has been a lot of research done on teamwork. For example, research is being conducted in the field of management to understand what makes a good team, what improves team performance, and how to effectively recognize team situations (Salas & Fiore, 2004). In addition, today, much attention is being paid to competencies, which were introduced by McClelland of Harvard University in the 1970s and are behavioral traits common to high achievers. In today's world, where unexpected problems occur frequently, competency is an important element in team projects and is one of the factors that improve team performance (Yamashita & Hasegawa, 2020). However, there is a lack of research on the impact of individual competencies on team performance under unforeseen circumstances, especially on the impact of improvisation education on individual behavioral characteristics. As the research question, "How does the improvisation education affect individual teamwork competencies?" has been picked up. This paper examines how individual teamwork competencies (team orientation, back-up, teamwork, and leadership skills) affect team performance under unforeseen circumstances and investigates the impact of improvisation education on individual competencies.

2 Methodology

2.1 Ability changing experiment

2.1.1 Content of the Pre-Post OMG questionnaire

A questionnaire was administered before and after the OMG to investigate changes in individual teamwork abilities before and after the OMG. The questions were developed based on the results of Dickson & McIntyre's study (Dickson & McIntyre, 1997), referring to the teamwork skills defined by Aikawa et al (Aikawa, 2012). as consisting of team thinking skills, backup skills, monitoring skills, and leadership skills.

Table 1. Content of the Pre-OMG questionnaire

Questions	
1. What do you think it is the most important factor to work in a group under unexpected situation such as OMG experience? (Single or Multiple answer are allowable)	
Team-oriented	Keep pace with members/Make sure there are no disagreements
	Keep the group balance/Consider and accept different values
	Clearly assert your opinion
Backup	Encourage when members are negative
	Give an advice to the members/Provide acquired information
	Support members whose work hasn't finished
Monitoring	Check and confirm the progress of the member's work
	Listen to the member's opinion and reflect to yours
	Compare the opinion of yours and the members throughout the discussion
Leadership	Provide your knowledge willingly
	Create a positive atmosphere for the team
	Get along with your team members equally
	Find the best solution to failure and take action
	Others
2. How do you feel or want to be after your group have accomplished the OMG experience? (Free description)	

Table 2. Content of the Post-OMG questionnaire

Questions	
1. Which of these elements were difficult throughout OMG experience? (Single or Multiple answer are allowable)	
Team-oriented	Keep pace with members/Make sure there are no disagreements
	Keep the group balance/Consider and accept different values
	Clearly assert your opinion
Backup	Encourage when members are negative
	Give an advice to the members/Provide acquired information
	Support members whose work hasn't finished
Monitoring	Check and confirm the progress of the member's work
	Listen to the member's opinion and reflect to yours
	Compare the opinion of yours and the members throughout the discussion
Leadership	Provide your knowledge willingly
	Create a positive atmosphere for the team
	Get along with your team members equally
	Find the best solution to failure and take action
	Others
2. Please write down at least one improvement or suggestion for your better team performance based on OMG experience. (Free description)	

2.1.2 Subject and Conditions

The survey was held at SIT Omiya December 2019 and KMUTT in February 2020. For CEP2019@Omiya and CEP2020@KMUTT, it was conducted to participants majoring science and engineering (Table 4). Each Pre-OMG questionnaire was conducted on day4, and on day6 for Post-OMG questionnaire.

Table 3. Breakdown of the respondents for CEP2019@Omiya and CEP2020@KMUTT

CEP2019@Omiya

Nationality	Respondent	
	Pre-OMG	Post-OMG
Japan	32 (42%)	27 (38%)
Malaysia	3 (4%)	3 (4%)
China	5 (7%)	5 (7%)
Thailand	14 (18%)	17 (24%)
Vietnam	5 (7%)	5 (7%)
India	3 (4%)	2 (3%)
Indonesia	3 (4%)	3 (4%)
Brazil	3 (4%)	3 (4%)
Netherland	1 (1%)	1 (1%)
Poland	2 (3%)	2 (3%)
Brunei	1 (1%)	1 (1%)
Mongolia	2 (3%)	1 (1%)
Cambodia	1 (1%)	1 (1%)
Australia	1 (1%)	1 (1%)
Singapore	0 (0%)	1 (1%)
Taiwan	0 (0%)	1 (1%)
Total	76 (100%)	74 (100%)

CEP2020@KMUTT

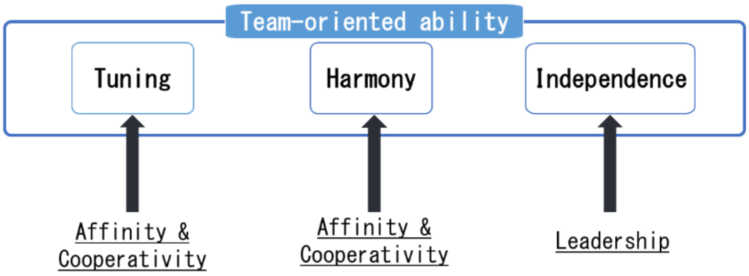
Nationality	Respondent	
	Pre-OMG	Post-OMG
Japan	19 (58%)	15 (63%)
Thailand	13 (39%)	7 (29%)
Indonesia	1 (3%)	1 (4%)
Laos	0 (0%)	1 (4%)
Total	33 (100%)	24 (100%)

2.2 PROG test

In order to measure the competency skills of the students, we administered the PROG test (Progress Report On Generic skills). This PROG test is provided by KAWAIJUKU and RIASEC. They created a database of the behavioral characteristics of young leaders active in the real world and extracted response patterns from it. After that, a scoring logic is constructed, and in addition to self-evaluation, an objective evaluation index is provided to enable a composite evaluation of generic skills. This PROG test was given to the students after the completion of CEP.

2.3 Linking team-oriented ability with result of PROG test

By linking the results of the questionnaire in section 2.1.1 with the results of the PROG test, we investigated the impact of OMG on individual teamwork skills. In the pre-OMG questionnaire, those who answered that the element was important were grouped into Pre-group1, and those who did not answer that the element was important were grouped into Pre-group2. Similarly, for the Post-OMG questionnaire, those who answered that the element was difficult were designated as Post-group 1, and those who did not answer that the element was difficult were designated as Post-group 2. Next, the results of the questionnaire and the PROG test were linked. Figure 2 below shows the team-oriented competencies in the questionnaire results and the corresponding competency components of the PROG test. the PROG test scores of the students in each group were extracted, and then the scores for each element were averaged. Then, a significance test was conducted on the differences in the mean scores of each group.



Affinity	Cooperativity	Leadership
Familiarity	Cognition	Discussing
Attentive	Information sharing	Claiming
Empathy	Mutual support	Creative discussion
Accepting diversity	Motivating others	Negotiation
Networking		
Trust building		

Figure 2. Corresponding table

3 Results and Discussion

3.1 Team-oriented ability changes due to OMG

The results of the questionnaires conducted for Pre-OMG and Post-OMG are shown below. Figure 3 shows the results of the CEP2019@Omiya questionnaire, and Figure 4 shows the results of the CEP2020@KMUTT questionnaire. The numbers in the figures correspond to the numbers in Figure 5. From Figure 3 and 4, we can see that the team-oriented ability increased in Post from Pre. This can be attributed to the fact that students have come to place more importance on team-oriented skills through OMG.

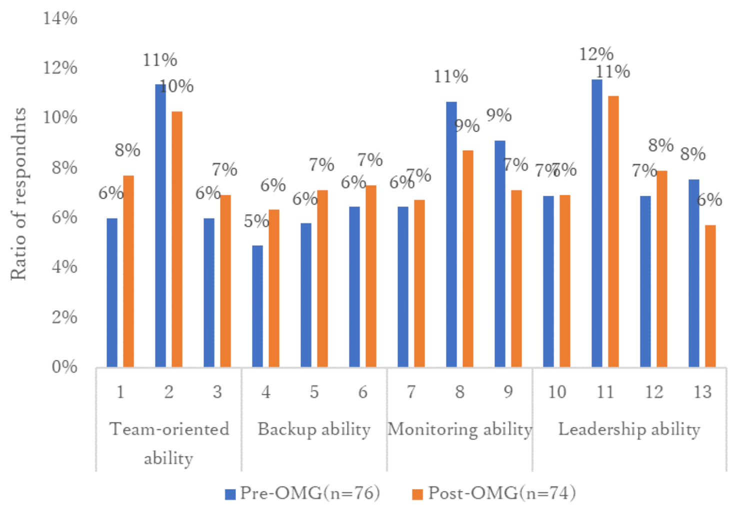


Figure 3. Changes in four types of abilities between Pre and Post OMG for CEP2019@Omiya

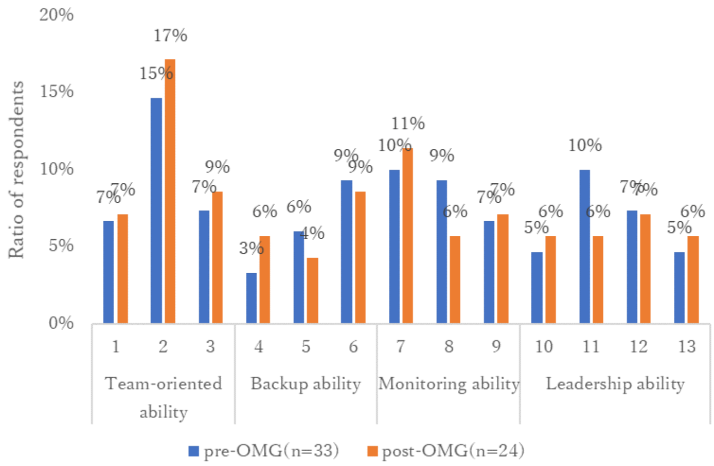


Figure 4. Changes in four types of abilities between Pre and Post OMG for CEP2020@KMUTT

1. Keep pace with members/Make sure there are no disagreements
2. Keep the group balance/Consider and accept different values
3. Clearly assert your opinion
4. Encourage when members are negative
5. Give an advice to the members/Provide acquired information
6. Support members whose work hasn't finished
7. Check and confirm the progress of the member's work
8. Listen to the member's opinion and reflect to yours
9. Compare the opinion of yours and the members throughout the discussion
10. Provide your knowledge willingly
11. Create a positive atmosphere for the team
12. Get along with your team members equally
13. Find the best solution to failure and take action

Figure 5. Choices for the questionnaire

3.2 Correlation between team-oriented ability and result of PROG test

From section 2.3, we present the results of the significant difference test for the differences in the mean scores of each group. First, Figure 6 shows the mean scores of the OMGs conducted at CEP2019@Omiya that showed significant differences. Note that in Figures 6 to 9, the * mark means that there was a significant difference (p<.05), and the † mark means that there was a significant trend (p<.10).

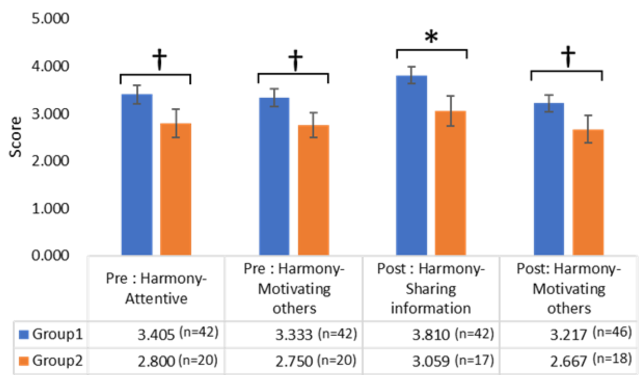


Figure 6. Harmony for CEP2019@Omiya

Next, the significant differences in the mean scores of the OMGs performed in CEP2020@KMUTT are shown in Figures 7 through 9.

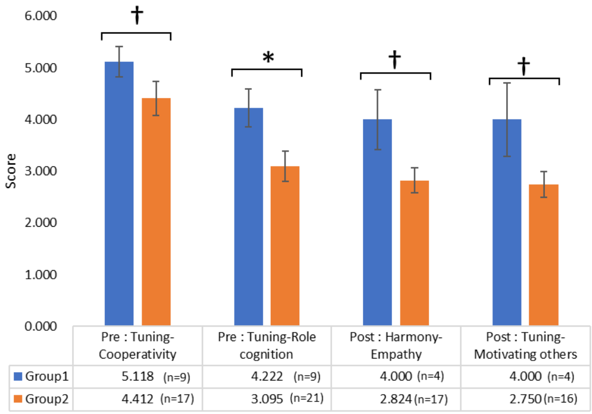


Figure 7. Tuning for CEP2020@KMUTT

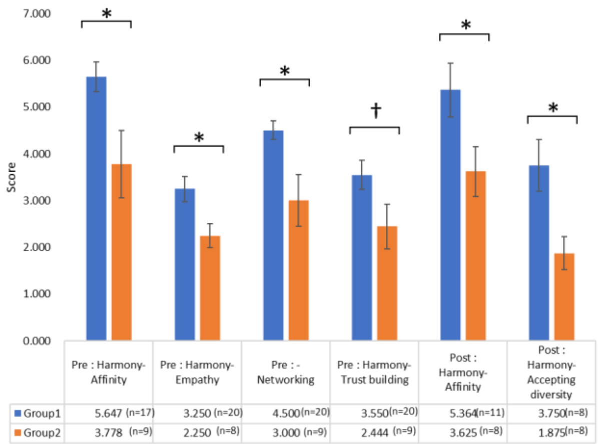


Figure 8. Harmony for CEP2020@KMUTT

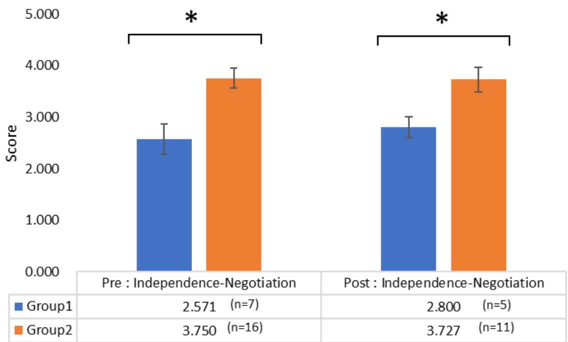


Figure 9. Independence for CEP2020@KMUTT

From this analysis of the questionnaire for the OMG experience at CEP2019@Omiya, Figures 6 through 8 show that the mean score for Group 1 was higher than that for Group 2 with a significant difference or a significant trend. This means that in the pre-semester, those who originally had a high level of ability placed importance on this ability, while in the post-semester, the mean score of those who found this element difficult was higher than that of those who did not, suggesting that they were aware of this element during the OMG experience and found it difficult. It seems that they are at the stage of conscious maturity. On the other hand, Figure 9 shows that the average score of Group 2 was higher than that of Group 1 in both Pre and Post. This may be since they are in the stage of unconscious maturity and are not aware of the importance or difficulty of the task in the first place.

4 Conclusion

In this paper, the impact of OMG on individual teamwork ability was discussed by relating it to individual competencies. The results confirmed that team-oriented ability is an important factor for teamwork in OMG. Therefore, we believe that improvisation education changes individual teamwork competencies. As a future prospect, we will continue to conduct questionnaires and surveys in the same way to investigate the impact on individual teamwork ability. We will also improve the OMG based on the results revealed in this study to improve the behavioural characteristics necessary to produce higher quality deliverables.

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Project-Based Learning in Robotics Subject of a Master's Degree

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Abstract

The work presented here is part of the development and implementation of methodologies that promote a more reflective, autonomous, collaborative, participatory and meaningful learning, based on entrepreneurship and learning to learn. It is about introducing project-based learning in the Robotics subject of the master's degree in Automation and Robotics. This subject has been taught for the previous 10 courses in a traditional way, that is, with theoretical classes in a lecture format, where the teacher taught the theoretical contents within the framework of an oral presentation with questions from the students during the presentation or at the end of it. In addition, a series of guided practice exercises were taught, where students consolidated the theoretical contents and acquired the practical skills of the subject. Upon the proposal of the use of projects to manage student learning, it is intended that they are the ones who acquire the necessary knowledge to solve the projects. The teacher becomes a director in the learning process, providing the necessary material so that the student may continue with the development of their real project, understanding each theoretical concept involved in it. One of the main problems that teachers of the subject have encountered over the last 10 years in this subject is that students possess different Engineering profiles. Project-based learning allows teachers to assess the depth in learning specific concepts, so that the subject can add value to all students. In order to know information, an anonymous survey has been carried out that allows for knowing various aspects of the proposed methodology. As students worked in groups, we also consulted about the operation of the group. An individual report of the work carried out was also requested, as well as a group report. All these documents allow teachers to discover the strengths and weaknesses of the proposed methodology.

Keywords: Project-Based Learning; Robotics Education; Engineering Teaching.

1 Introduction

This document describes the experience acquired when introducing Project-Based Learning (PBL) in the teaching of the Robotics subject of the Master's Degree in Automation and Robotics at the University of Alicante. This compulsory 60-hour course is taught intensively in 12 sessions of 5 hours separated in three weeks. This is an important factor when it comes to understanding the operation of the subject and how an active learning methodology such as PBL will affect the acquisition of the different competences.

It is also important to highlight the entry profile of the students who regularly study this master. Although mostly this profile corresponds to mechanical, industrial, automatic, or electronic engineering, it is also very common for students with a degree in computer engineering to study it. Any engineering will give access to study this Master. Robotics is a very transversal subject, requiring knowledge from many important engineering subjects, such as mechanical design, kinematics, sensors, automatic control, microcontrollers, programming languages, and software algorithms development. These subjects are not taught in the same way in the different engineering degrees. Thus, computer engineers have a great knowledge of programming languages, algorithm, and software development, or even microcontrollers, but not so much in automatic control, sensors, kinematics, or mechanical design. Just the opposite happens with an industrial engineer. Hence, the teachers of this subject have encountered year after year with serious difficulties in homogenizing knowledge while explaining the matter.

In order to design an active learning strategy in this subject, it is important to review the learning outcomes required in the verified memory of the title:

- Develop reports with proposals for robotic systems that meet the necessary requirements for their application.
- Identify the equipment that different companies can offer and deduce the most appropriate according to the application to be carried out.
- Develop robot programming projects according to their specific language.
- Discriminate the advantages of using object-oriented programming languages for the implementation of programs for robotic systems.
- Compare the most widely used software schemes for the design and development of robotic system controllers.
- Implement the motion controllers of any robotic system to generate complex programs that solve any task.
- Determine the most used artificial intelligence schemes in applications with robotic systems.

This subject has been taught for the previous 10 courses in a traditional way. The teachers made available to the students a series of documents with the slides that they later explained in class. They were classes of 2.5 hours in which the student was unable to follow the common thread beyond the first hour. These theoretical classes were complemented with practical classes, also lasting 2.5 hours, where practical exercises were proposed for programming the different robots available in the robotics laboratory of the University of Alicante (see Fig. 1).

Figure 1. Robotics Laboratory of the University of Alicante.

In order to provide the student with active learning, PBL has been chosen because it is a teaching method in which teaching and learning activities are organized around a project to achieve the desired learning outcomes of the course (Sanchez-Romero, 2019). The teacher assumes a client role in which the students form a small company that will provide the service demanded by the teacher. Students, as a team, work together to solve complex robotic engineering problems, participate in decision making, and demonstrate leadership on a variety of tasks over a period of time to achieve project-specific deliverables. PBL can be used to improve student learning, as well as to improve student participation in the teaching/learning process and achieve higher levels of involvement (Lacuesta, 2009). PBL has also made it possible to further customize the level of entry-level learning outcomes for different entry-level engineering profiles.

2 PBL & Robotics

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), when the name of problem-based learning methodology appeared for the first time. This method quickly spread to European Universities in the 1970s. It is in this decade that 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 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. Its 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.

Robotics is a field where it is relatively easy to propose didactic projects. It is a subject in which many topics take part, such as mechanical design, kinematics, dynamics, sensors, automatic control, microcontrollers, programming languages or frameworks for advanced software development. The interconnection of many of the issues listed in any robotics project makes a robotics subject ideal for the implementation of a PBL methodology (Hung, 2002). Indeed, in the literature, there are several works such as (Ghaleb, 2020; Qidway, 2011; Piguet, 2002), where experiences related to the use of robots within the framework of PBL are presented.

It is easy to find works related to PBL that describe projects that students carry out to learn concepts other than robotics, but using a robot (Carbonaro, 2004; Hamblen, 2004). In (SantClair, 2021) it is possible to find cases in elementary schools for which the construction and programming of a robot is used with the aim of teaching concepts of electronics, mechanics, or programming (Zadok, 2018). At the University, the use of the robot in the project is already focusing more on the acquisition of concepts of robotics (Havenga, 2020; Montagner, 2018). Although they are very directed projects, they leave little chance for the student to decide which path to take and how to develop it from scratch. The most common is to find jobs that focus on another subject related to robotics, such as industrial computing, which is taught through the construction and programming of a 2-degree-of-freedom robot with the LEGO Mindstorm platform in (Calvo, 2018), or by building and controlling a prototype of a low-cost robot controlled by a joystick in (Hassan, 2015).

3 Methodology

This section describes the methodology used to introduce the PBL in the teaching of this course of the robotics subject. In the first place, the participating students will be described, then the projects offered are summarized, emphasizing the theoretical and practical concepts where the subject is most affected. To ensure that theoretical concepts are acquired, two gamification experiments are performed using Kahoot! The section ends by briefly explaining this approach that complements the use of PBL in the subject.

3.1 Participants

Students enrolled during the course in which the PBL methodology is tested enter the Master's degree through very different degrees. 23 students participated in the subject in this last course. Table 1 shows the access profile grouped according to degree studied.

As indicated above, the entry profile is relevant, since not all degrees provide the same basic competencies for a subject as multidisciplinary as robotics. Thus, Robotic Engineers have a great knowledge of the kinematics and dynamics of robots, their programming, as well as their control. However, mechanical engineers, to take another example, do not have a large programming base, but they have a greater knowledge of the mechanical design of robots.

On this basis and based on the learning results to be achieved in the subject, the teaching staff defined 6 projects. To divide the group of 23 students and assign one of the 6 projects to each subgroup, an initial survey was carried out at the beginning of the course. The survey consisted of 3 questions. The first one asked about the knowledge of robotics they had at that time: robot structure, typology, kinematics, dynamics, programming environments (which ones), etc. In the second question they were asked about programming knowledge and the programming languages in which they had programmed. Finally, they were asked about their preference of working with an industrial robotics project or with a service robotics project.

Table 1. Entry profile of students enrolled in the 2020-21 academic year in the Robotics subject.

Degree	**Number of students**
Robotic Engineering	8
Electronic Engineering and Industrial Automation	6
Industrial Electronic Engineering	4
Mechanical Engineering	2
Industrial Engineering	1
Mechatronics Engineering	1

3.2 Robotic projects offered

Once the different groups had been created and the projects were assigned to each one of them, they began to work on the project. Due to COVID-19, teaching strategy was organized in a dual way. For this, the class was divided into 2 large groups. Thus, working groups 1, 3 and 5 attended together in person (3 groups can be seen working with the robots in Fig. 2). This allowed each group to work with the robots more easily. At the same time, the other groups were assigned a Google Meet room for each one of them. So, if any group needed to consult something, they indicated it in a WhatsApp group and the teacher immediately answered their questions. The presence alternated daily, so the operation was quite fluid.

Figure 2. Students working on the different projects during the classes of the subject.

The projects that were offered to the students are described below.

3.2.1 Project 1. Simulation of a robotic cell in CoppeliaSim with a UR3 and control of the real robot.

In this project it is proposed to work with the UR3 collaborative robot from Universal Robots to carry out a simulation of an industrial task. First of all, to simulate the process, the CoppeliaSim simulator is used. It uses a vision system integrated in the program that recognizes the objects, and the inverse kinematics module for the calculation and programming of trajectories. The objective of the project is to synchronize the trajectories generated in the simulator with those of the real robot, so a Python program is in charge of implementing the real robot controller and establishing the connection between the simulated robot and the real one by using TCP/IP protocol sockets. In this project different strategies for the control of the real robot are tackled. In this way, concepts of path planning, concepts of direct and inverse kinematics of the robot, aspects of sending trajectories to the real robot, communications, etc. are worked on.

3.2.2 Project 2. Simulation of a robotic cell in RobotStudio with two ABB IRB120 controlled by Matlab and synchronization with the real robots.

In this project, two ABB IRB120 robots are used to simulate an industrial task. It makes use of a vision system integrated in the program itself that recognizes the objects and the inverse kinematics module for the calculation and programming of trajectories. Concepts of path planning, concepts of direct and inverse kinematics of the robot, aspects of sending trajectories to the real robot and communications are worked on. Matlab is used for performing the control computation and connected to a RobotStudio server to perform the simulation.

3.2.3 Project 3. Teleoperation of a collaborative robot Kinova Mico 2 through keyboard commands: Cartesian and articular movements.

In this project, it is proposed to carry out the remote control of a Kinova MICO2 robotic arm operated through the keyboard. The most effective control method should be studied in accordance with the system requirements, having control options in Cartesian and articular space and these, in turn, by position or speed. Concepts of direct and inverse kinematics, aspects of control by position or speed, as well as real robot programming are developed. It is programmed with the robot's own API, on C++.

3.2.4 Project 4. Guidance of a UR3 collaborative robotic arm through image-based visual servoing.

Image-based visual servoing is a control technique that allows for a robot to be guided only through successive images captured by a camera. In this project, a visual servoing system is developed that allows guiding the robot, a UR3 collaborative robot, from any position to a desired final position. A pattern of characteristics is used for guidance. Concepts of transformation of coordinates between the different reference systems, concepts of inverse kinematics of the robot, aspects of sending trajectories to the real robot and synchronization with external signals are worked on to activate the camera and obtain each one of the frames. Everything programmed over Matlab, ROS, or through any application developed in C ++, .NET or Python.

3.2.5 Project 5. Construction of a tower using an ABB IRB120 through ROS.

In this project, a tower is built with wooden parts using an ABB IRB120 robot. For this, the necessary movements of the robot are programmed from ROS. Concepts of trajectory planning, inverse kinematics of the robot, and aspects of sending trajectories to the real robot, communications are worked on. Aspects of ROS are developed at a basic level and work is done on a RobotStudio server that allows it to be connected to ROS.

3.2.6 Project 6. Automated stop motion with an ABB IRB120 robot.

In this project, one of the ABB IRB120 is used to automatically generate each of the frames of a stop motion video. The objective is to be able to create this video through the positioning of the objects that appear in the scene by means of the industrial robotic arm. More complex concepts of trajectory planning, concepts of inverse kinematics of the robot, aspects of sending trajectories to the real robot and synchronization with external signals are worked on to activate the camera and obtain each one of the frames. All programmed over RobotStudio and RAPID.

3.3 Gamification and M-Learning

The theoretical content of the subject was taught through 1 hour master classes, where the teachers explain the subject based on slides with audiovisual content. To complement the acquisition of the theoretical content, two competitions were held through Kahoot! with online questionnaires. The questions that appeared in the questionnaires were mainly of two types: true/false questions and multiple-choice questions (4 possible answers). Each question is asked at the same time to all the students, so that the sooner it is answered, the more points are obtained. When the time for the question runs out (or all the students have answered), a summary is shown with the position up to that moment of the 5 best global scores. The three best students in each competition received an award in the form of an extra score for the final grade for the course. The most interesting thing about the two competitions held, however, is that the teachers were able to use this questionnaire to, once finished, go over the questions one by one and explain each of the correct answers. This helped a lot to consolidate specific theoretical concepts that were difficult to clarify within the framework of their projects.

4 Results

A study has been carried out on how PBL methodology has affected the final grades. It is important to emphasize that the grades have improved, but they did not start from bad results that had to be improved. The main objective of the methodology was to achieve a better integration of the different access profiles to the master. Therefore, in this section we will also show a summary of the final survey carried out, where the students, freely and anonymously, described their main opinions about the methodology used in the subject.

We begin the analysis of the results of the implementation of the PBL methodology by talking about the students' grades. In Fig. 3 the improvement obtained in the final grade during this course compared to previous courses can be seen. The normal distribution has shifted towards 9/10. It is also important to analyze the data related to the students' marks in the final theory exam. This exam is composed of 20 multiple-choice questions with theoretical concepts. The grades this year have improved a lot (see Fig. 3). In part, we understand that because the project encouraged them to understand these theoretical concepts to continue moving forward, and in part because of those two questionnaires carried out in Kahoot! The result is very promising and should be ratified in subsequent courses, but it is observed that the PBL not only improves the acquisition of the practical skills of the subject (something that was to be expected), but it has also considerably improved the acquisition of theory skills of the subject.

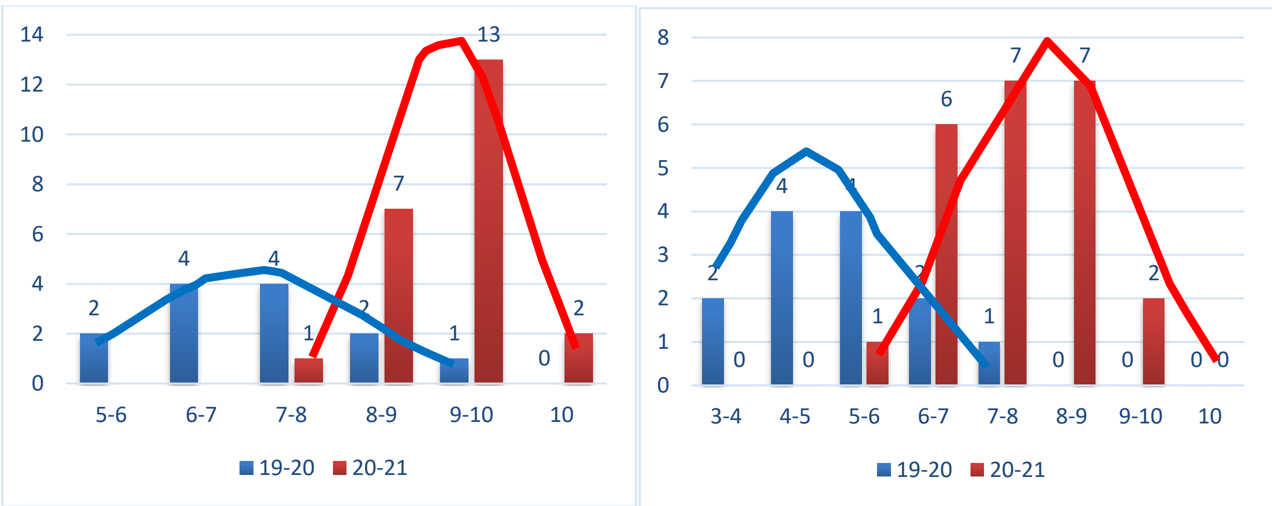

Figure 3. Left: Final grades of the subject in the last two courses; Right: Theory exam grades of the subject in the last two courses.

The other aspect to be analyzed is related with the opinion of the students regarding the PBL methodology. The survey carried out can be seen in Table 2. Although not all the questions are closely related to the methodology, they are indirectly. The first three are specific questions about the PBL methodology. The free response mode has worked very well so as not to restrict the student's thinking by anchoring it to a discrete structure of the typical surveys with responses from 1 to 5. In these first three questions we wanted to know if the student liked the PBL methodology, if it has seemed more difficult than a traditional methodology, and if they have aroused more interest in the subject learning from a very specific project. The responses are very positive towards the proposed methodology. 95% indicate that they like the teaching format, 90% affirm that it has not seemed more difficult than a classical methodology, while 100% affirm that the use of this methodology has aroused more interest in the subject.

In questions Q4, Q5 and Q6, it is intended to obtain the opinion regarding group work. Aspects such as if they have had a conflict and how they have solved it, or how the work has been divided and if they have detected any imbalance in the workload towards a member of the specific group were asked here. In this regard, no problem has been indicated, 100% are happy with how the work has been divided and they consider that there has not been much imbalance in the workload of the different members of the group.

In the block of questions from Q7 to Q11, the subject is asked in general, if they think the subject contributes what they expected for their professional future, how they would improve it, as well as what opinion those who already knew basic concepts of robotics and those who had no prior knowledge have. Regarding question Q7, the students answered affirmatively in a general way (85%). However, it is important to emphasize a comment that the remaining 15% agreed, and it is that they think that they would have liked to know more details of the projects carried out by the other groups, since each group was focused on its own project and had not time to see what the rest did. In this regard, it is important to write it down in order to improve it in future editions of the course. Perhaps a simple solution would be a presentation session on the last day of class where each group tells how their project has been carried out. In the question about how they would improve the teaching of the subject, interesting advice were obtained. The most recurrent was to make short videos with specific theory topics so that those who need to expand these concepts can do so at their own pace. From the answers to questions Q10 and Q11 we can conclude that the subject has contributed to students who already knew about robotics, and that students who had no previous knowledge are now able to face a robotics project. However, they highlight the need to better consolidate theoretical knowledge, an aspect that could be solved with those videos that they themselves indicated in question Q9.

Question Q12 asks about the work of teachers. 100% affirm that teachers have been able to motivate them to improve their knowledge of the subject. As for whether they have been able to guide them with the project, 10% indicate that they would have liked a little more guidance at the beginning of the project.

Finally, in the last question, they are asked to give themselves a global grade to know how they value their own work in the subject. We can see grades from 6/10 to 10/10 in this self-assessment. But it is true that they themselves were much more demanding than the final grades obtained.

Table 2. Final survey of the subject.

Q1	Did you like the teaching format of the subject using PBL?
Q2	Has it seemed more difficult than a classical methodology?
Q3	Has it caused more/less interest in the subject?
Q4	How has the experience of working in a group been? Have there been any conflicts? If so, how have you solved them?
Q5	Are you happy with how the work has been divided between the members of the group?
Q6	Do you think there has been a lot of imbalance when it comes to the work done by each other?
Q7	Do you think that this subject has given you what you expected of it for your professional future?
Q8	If the subject was not compulsory to obtain the master, would you recommend to a friend of yours to take it?
Q9	How would you improve the teaching of the subject?
Q10	If you already knew about robotics, what has the subject given you? What have you missed?
Q11	If you did not know about robotics, do you think that now you would know how to start a robotics project? What have you missed?
Q12	Have the teachers been able to motivate you to improve your knowledge of robotics? Have they been able to guide you in the project?
Q13	What overall grade would you give yourself in the subject?

5 Conclusion

In general, the students expressed their satisfaction with the training received through the project, they consider that they have learned independently, and that they have acquired research experience. They especially value the fact of working with real robots and with objectives like those that can be asked in the professional world. Most consider that the chosen project has been adequate, and the motivation and stimulation that it has produced has been positively valued. Regarding competencies, the students say that the project has allowed them to gain valuable experience of teamwork, that it has allowed them to put their own initiatives into practice and that they have not had to follow any scripts. For their part, the teachers consider that the PBL methodology is stimulating. The level of understanding between the teacher and the students is high, and a learning environment is created marked by the predisposition of the students. In terms of teaching objectives, the activities developed within the framework of the project have exceeded in quantity and depth the activities that were proposed in traditional laboratory practices. The open nature of the project has allowed students to have different approaches to their solutions, thus sparking authentic discussions about possible solutions. In short, the students have felt like true engineers who have participated in the conception of a complex system. This methodology allows much better personalization of the learning of the different entry profile. Teachers have more time for personalized attention to guide the learning process of each student, so that they can better serve students who require more attention in a specific aspect of the subject, leaving the rest of the students to focus their learning on other aspects of the subject where they had less knowledge base.

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A new remote laboratory of a pumping system designed using a low-cost hardware model

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Abstract

Automatics and Control subjects are always improved when the classroom teaching is supported by adequate laboratory experiments in order to provide students a deep understanding of theoretical lessons. However, both expensive equipment and limited time prevent teachers from having enough educational platforms. Thus, several low cost and flexible solutions have been developed to permit an effective teaching in Automatics and Control at a reasonable cost. Virtual and remote laboratories are inside this group of solutions as Web-based experimentation tools which have demonstrated the importance and effectiveness of hand-on experiences. This paper presents a new remote laboratory of a pumping system. The developed application allows students to remotely practice different theoretical concepts on the industrial process, which has been designed using a low-cost hardware model. In this paper, the most important features of the remote laboratory are described. The application proposes a set of practical experiences which students must resolve making use of the remote laboratory.

Keywords: Automation, e-learning, PLC programming, remote laboratory.

1 Introduction

Experimentation is one of the most important issues for engineering students, not only because it allows them to observe and explore real-world applications but also because it helps to develop a deep understanding of theoretical lessons. The subjects of Automation and Control require experimentation with real equipment as, for example, the PLC (Programmable Logic Controller).

One of the guidelines determined by ESHE (European Space of Higher Education) is that traditional education must be combined with distance education, because a good distance teaching education provides flexibility to students. In this new educational context, and in the field of Automatics and Control education, virtual and remote laboratories play an important role because they are designed for an independent learner and/or a distance self-learning (Heradio et al., 2016). In the case of remote labs, these allow students to practice with real physical equipment located in remote places being accessible at any time and place with an Internet connection.

In Automatics and Control teaching, there are several low-cost remote laboratories via the Internet that facilitates the development of new educational methodologies in this field (Domínguez et. al., 2005). For example, different remote-control laboratories for conducting teaching practices through the Internet were presented in (Costa-Castelló et. al., 2010). Other remote laboratory based on very low-cost devices is presented in (Kalúz et. al., 2014). In this case, a remote laboratory for control education was developed using Raspberry and Arduino. In addition, several approaches have developed remote laboratories which allow real experimentation of hardware models that emulates real systems. This is the case of the works presented in (Kalúz et. al., 2014; Angulo & García-Zubía, 2014), where a quadruple tank process and a three floors elevator were implemented with real industrial equipment. In this field, other approaches about remote labs have been developed for control of industrial processes (Domínguez et. al., 2014; Prada et. al., 2015; Del Canto et. al. 2015; Aydogmus & Aydogmus, 2009).

The work presented in this paper shows the successful application of a new remote laboratory used in the practical learning of the subjects “Automatic Control Systems” and “Automatics and Robotics” taught in the

Automatics and Robotics Master's Degree, and in the Computer Science Degree, both at the University of Alicante. The application allows students to remotely practice different theoretical concepts using the hardware model of a real industrial process (pumping system). The industrial process has been designed and implemented by a low-cost hardware model. Students remotely program the main controller of the plant and can visualize the results obtained via a web interface and video streaming feedback.

2 Remote laboratory description

2.1 Pumping process emulated by the remote laboratory

The aim of the controller of a real pumping system is to keep stable a pressure value in an industrial plant. For that end, one of the pumps must be controlled by an inverter with the output frequency needed to achieve the reference pressure value. When the water demand cannot be achieved with only one pump controlled by the inverter, one or more of the remaining pumps can be directly connected to the three-phase power line connection by means of contactors managed by the controller. In the case of an increase of the pressure (decrease in demand) pumps must be disconnected from the three-phase line. If there is not demand, the pump controlled by the inverter will be also disconnected. Furthermore, the system must control that all the pumps have the same use over time.

The hardware devices of the remote laboratory emulate a real case of a pumping station. Specifically, the real device emulated is the typical water distribution system of an industrial plant. In this case, the pumping system has 4 pumps and only one inverter. The controller of the pumping system must be able to adapt the system to any water demand using the 4 pumps and the inverter. For this purpose, a pressure sensor is connected to the main controller in order to give a pressure value of the distributed water (in a range of 0-10 bars, traduced to 4-20mA).

2.2 Hardware model of the remote lab

The hardware model of the pumping system is shown in Figure 1. It shows the following components:

- A three-phase motor of 4 magnetic poles.
- An inverter MX2 connected to the motor.
- A PLC type CP1L-J from OMRON.
- An HMI (Human Machine Interface) screen to monitor the hardware.
- Several output lights for the simulation of the state of the pumps.
- An Ethernet switch for the network connection.

As commented, this hardware model emulates a real pumping system of 4 pumps, which is in charge of maintaining a stable pressure of 6 bars regardless of the demand. The main controller of the industrial system is the CP1L, whose digital outputs are employed to indicate the pump controlled by the inverter MX2 (only one pump can be controlled at the same time) and to indicate the active pumps directly connected to the three-phase line (at 100% of their power). The three-phase motor represents the pump controlled by the inverter, which must send to the motor a correct frequency to maintain the pressure and to adjust the demand.

The CJ1 is in charge of simulating the industrial plant. This device runs a program in order to analyse the signals coming from the CP1L, such as the pump controlled by the inverter and the active pumps. An analog input of the CJ1 is used to read the speed of the motor controlled by the inverter.

The program of this last equipment produces as a result the calculated for the simulated pressure sensor (controlled and active pumps). This value of the transducer is sent through an analog signal directly to the MX2 inverter, so it is possible to use it as feedback input for the inverter PID controller. In addition, the CJ1 can load different profiles of water demand where the value of the demand changes in real time. These profiles of the demand are used as practical experiences for the students.

2.3 The remote laboratory

The hardware model presented has been implemented as a remote laboratory. Different software and hardware elements have been added in order to provide remote functionalities to students. Figure 3 shows the connections between the devices of the hardware model and the Internet.

Remote capabilities allow students to load their programs to the CP1L by means of the software of the PLC's manufacturer, connecting to a specific IP of the PLC. The router of the hardware architecture of the remote laboratory performs a NAT (Network Address Translation) for programming the PLC as a local IP using the cloud. The CJ1 is connected through Ethernet to a web server (see Figure 3). Through this connection, the server can send commands that modify certain memory parameters in the CP1L. The main purpose of this functionality is to generate a few demand/time profiles in the plant.

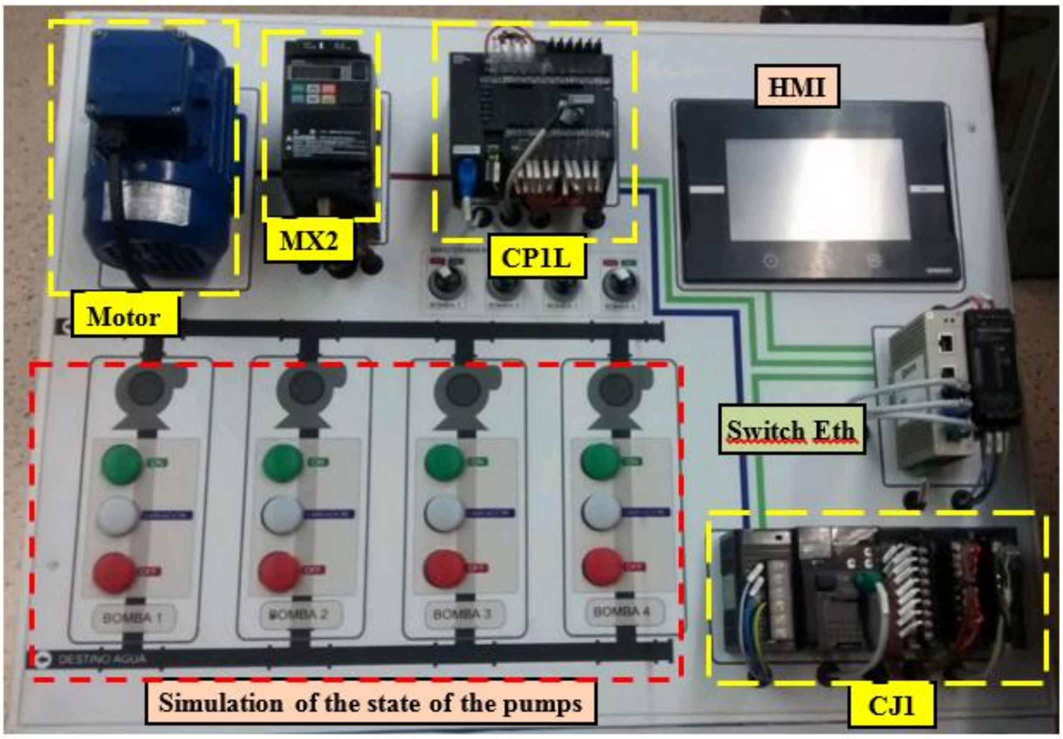

Figure 1. Hardware model of the pumping system

At the same time, through this connection, the web server monitors the status of the simulated plant: state of the pumps connected to the inverter, state of the pumps connected to the three-phase line, pumps in error state, demand, pressure transducer and motor speed (which simulate the controlled pump speed). This information is used to update a SCADA interface, which is shown to students, so they can follow the evolution of the plant under the control program loaded (see Figure 2). In addition, the server reflects the evolution in time of the different parameters of the given profile and generates several graphs that will be sent to the students. Then, students can analyse the response of their programs and fix the errors found in the response. The web server also performs a video-streaming feedback of the real plant in order to provide students a real state of the emulated pumping system (see Client Interface in Figure 3).

In terms of hardware and software description, the web server has been developed by low-cost hardware, specifically with a Raspberry Pi 3 and the camera Module V2. The communication between the web server and the plant (PLCs CP1L and CJ1) is performed by the Modbus protocol. SCADA interface has been developed in different languages such as C#, JavaScript, CSS and HTML. It also makes use of tools and libraries such as Entity Framework, MEF (Managed Extensibility Framework), AngularJS and SQL Server.

For a correct access of students to the remote plant, there are two critical services within the server: access restricted to registered students (with username and password) and a booking system, so that only one user can try to load the program and try to do the exercises. This booking system is a program that assigns a schedule (day and time) so the student can enter the system remotely through the Internet and perform the practical exercises.

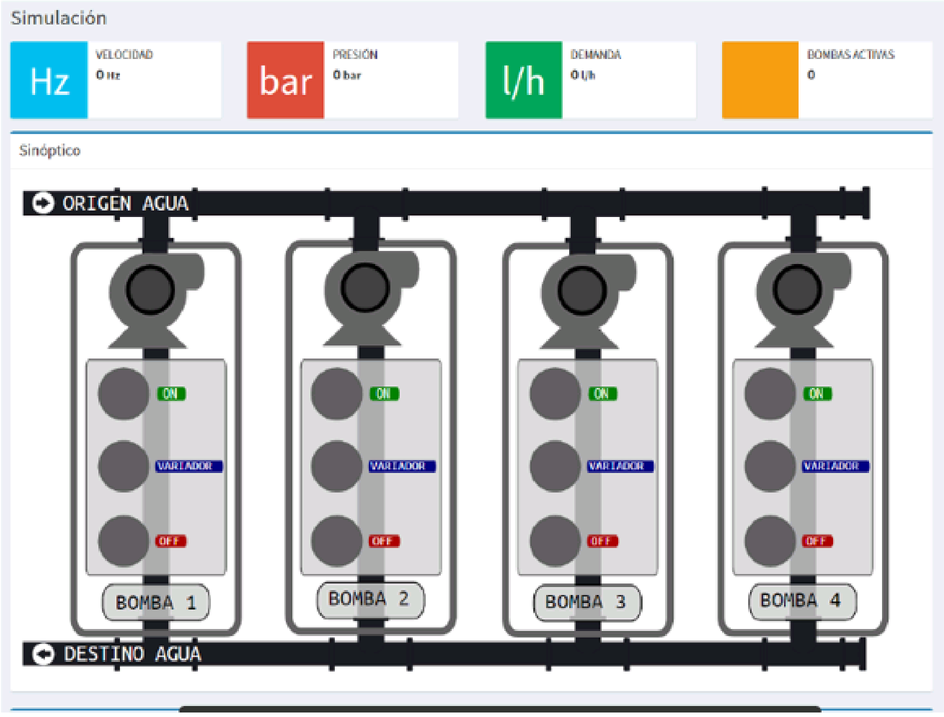

Figure 2. SCADA interface

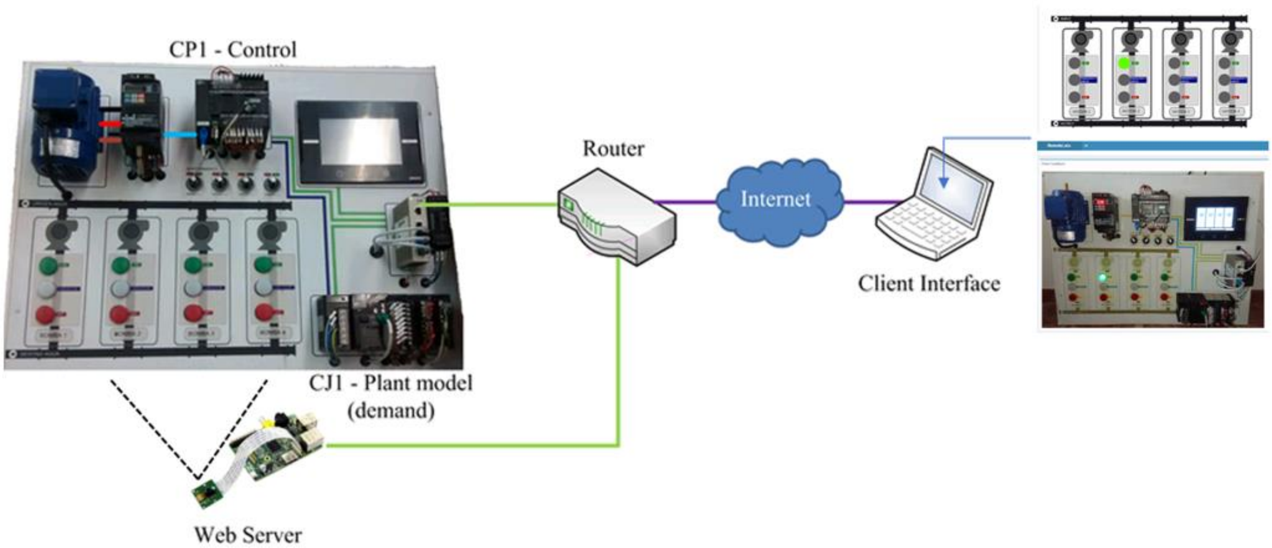

Figure 3. Remote laboratory description

3 Practical experiences

Practical experiences deal with different profiles of water demand for the pumping system. Students must program the main controller of the plant (CP1L) in order to perform a correct management of both the pumps and the inverter. In this section, a practical exercise of the remote plant is described.

Figure 4 shows a demand profile from the practical exercises of the students. This introduces an ascending ramp followed by a descending ramp and checks the output pressure of about 6 bars which must keep stable in the system.

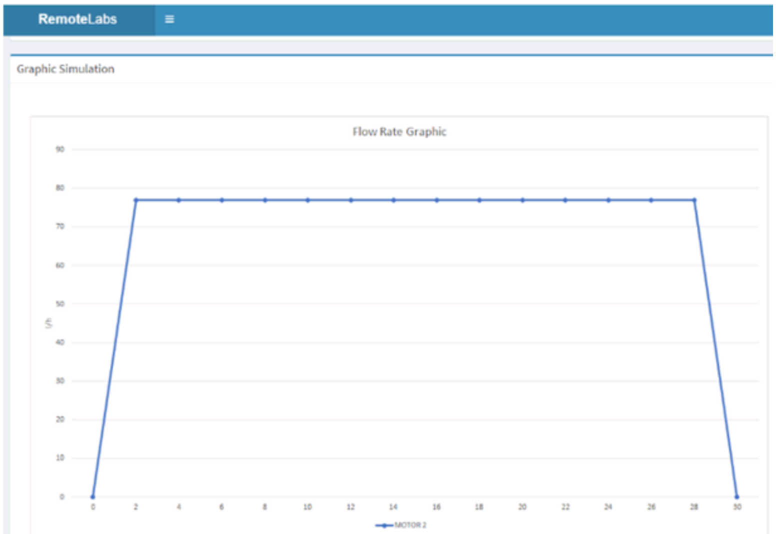

Figure 4. Practical exercise of the remote lab

The initial demand of the system is zero. This demand will progressively increase until 78m3/h. Once this demand is achieved, this value is maintained for 30 seconds and subsequently decreases until zero. The proposed system uses a PID controller in the MX2 inverter in order to assure a pressure of 6 bars during all the experiment. At the beginning of the experiment, the system connects the first pump when the demand begins (pump 1 in the example). This first pump will be the one controlled by the PID of the inverter in order to allow the system to regulate the pressure (Figure 5).

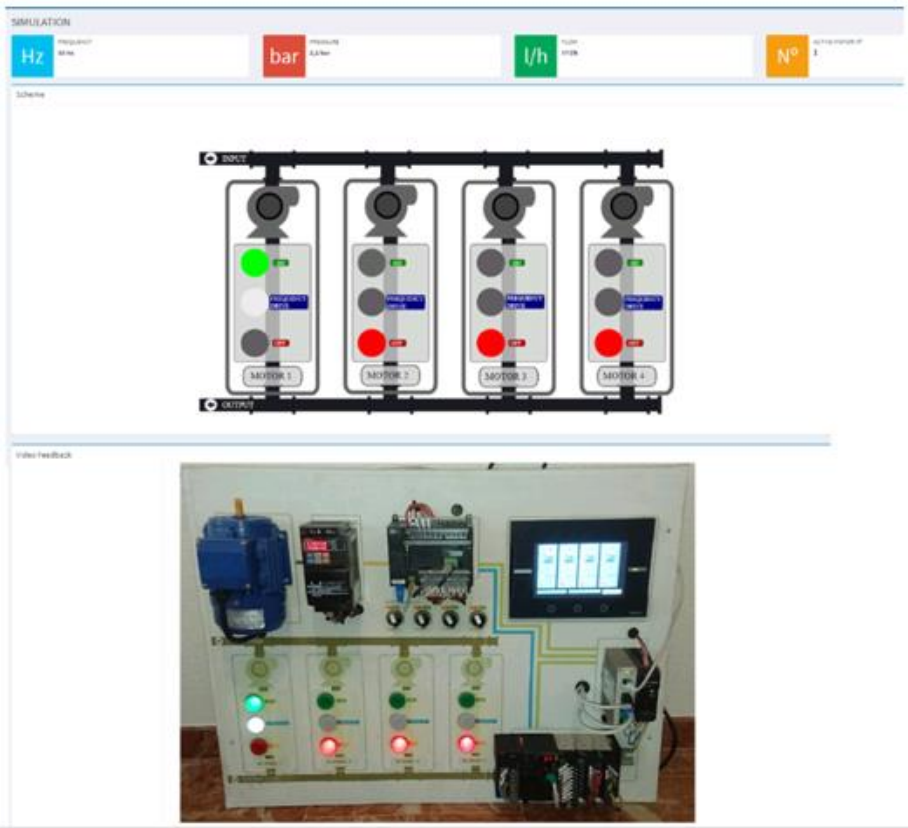

Figure 5. SCADA visualization and video feedback of the web environment (I)

After some time, the same thing will occur, i.e., the controlled pump has an output frequency of 50 Hz. Therefore, a new pump (pump 3) must be connected to the three-phase network (Figure 6). As previously indicated, after 27 seconds, the demand begins to decrease. When the frequency is 0 Hz during several seconds, the program implemented by the student must detect that an over-pressure is generated. Therefore, the program must to progressively deactivate the pumps connected to the three-phase network. The pumps must be deactivated considering the time used in each other in order to equalize the use of the pumps.

This situation will continue until all the pumps connected to the three-phase network are deactivated. Finally, the demand decreases until the controlled pump must be also deactivated, by stopping the inverter first and then deactivating the pump. Therefore, the student must develop a program in the CP1L with these points in order to perform a correct behaviour of the industrial system.

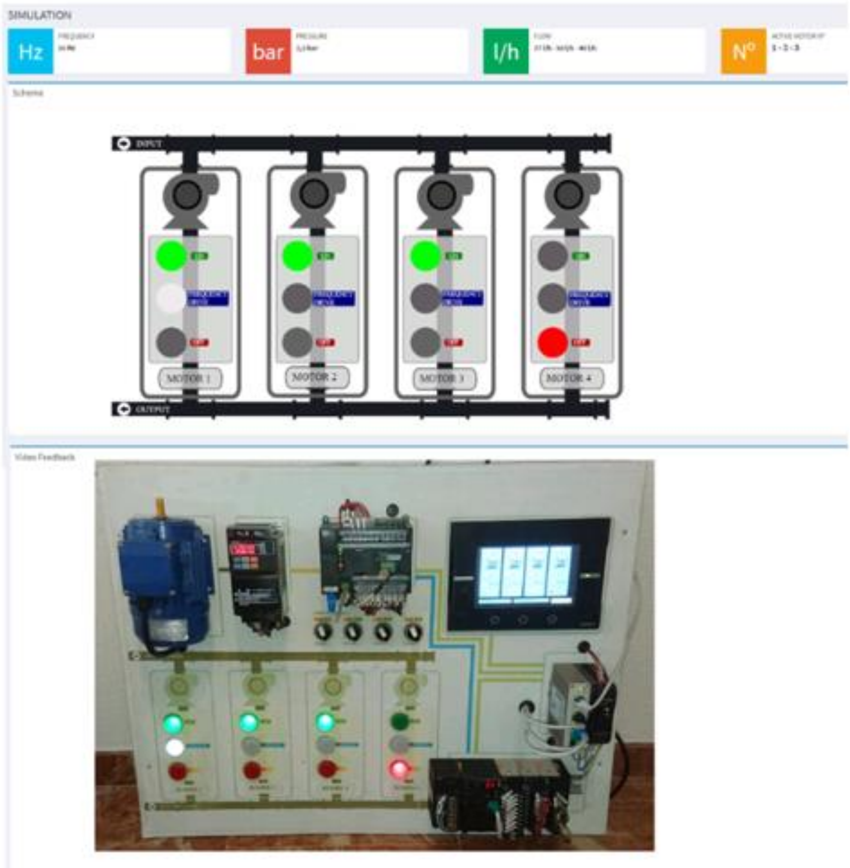

Figure 6. SCADA visualization and video feedback of the web environment (II)

4 Teaching framework

This approach is being used in the following courses with contents about industrial processes and automation: Automation and Robotics in the Computer Science Engineering Degree, and Automatic Control Systems in the Automatics and Robotics Master's Degree. In both, there are some didactic units about automation and control, where the main learning objectives are:

- To explain sensors and actuators employed in the industrial systems.
- To explain the PLC device and its operation principles.
- To teach how to use the PLC to control industrial processes.
- To explain how to program the PLC based on IEC1131-3 norm.
- To explain basic concepts about classic control theory such as PID controllers.

This application proposed has been integrated a blended learning educational methodology. Students, in the assistant classes perform the configuration of the MX2 inverter (first tasks). Afterwards, they can program the

PLC using the remote laboratory and the assistant classes. The main objective to reach by the remote laboratory is that students can implement, monitor and verify control and automation techniques from home as if they were in the industrial plant. This overall objective is specified in the following items:

- To have a hardware platform with similar features to those existing in an industrial environment. This way, students can practice concepts such as: adjustment of PID controllers, programming of PLCs, industrial communications and adjustment of inverter's parameters.
- To provide students a remote access to this hardware platform in order to perform experiments from home. The remote laboratory must be an environment for self-learning. For this objective, the system detects possible errors and offers the necessary feedback to the user.
- To have a self-assessment system. The system automatically establishes different operating modes or practical experiences to evaluate all the cases that may occur in a real industrial system.

This laboratory, with the features above commented, provides an improvement in the learning process of the student to be this active, self-directed, and constructive. The practical experiments proposed aim to evaluate the following concepts of operation in students about a real pumping industrial system:

- The suitable power on/off of the pumps and their time of operation.
- The adjustment of the frequency of the inverter and the PID controller.
- The communication task between the PLCs and the inverter.

5 Students' opinion

Most of the students consider this remote laboratory an efficient tool in the learning process that encourages their ability to understand control and automation concepts. In addition, they can experiment with real hand-on practices from their home as in the real laboratory, with a flexible timetable and providing more opportunities to try the response of their programs. Thus, this remote lab has improved student learning outcomes in terms of practical experiences.

Another question asked to the students was about the software to be installed, and the ease of use of the remote laboratory. None of the students had problems with the installation of the necessary software programs and they were able to adapt quickly to the user interfaces.

6 Conclusion

A new remote laboratory employed in the practical learning of the subjects "Automatic Control Systems" and "Automation and Robotics" taught in the Automatics and Robotics Master's Degree, and Computer Science Degree both at the University of Alicante, has been described. The presented application allows students to remotely practice different theoretical concepts using a hardware model of a real industrial process about a pumping system. The use of the proposed tool allows reinforcing students' active learning since they can perform practical exercises with the aim of understanding the acquired knowledge. In addition, students can understand the scope of theoretical concepts by applying them to a realistic industrial environment. As future work, authors are working in several aspects of the remote lab such as improving interfaces and model, and providing more practical exercises.

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Innovating to Improve – An Experience in a Computer Engineering Programme

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Abstract

This paper presents a pedagogical experience carried out in a course unit of a master's programme in Computer Engineering at the University of Minho. The course unit, Numerical Methods and Nonlinear Optimization, is placed in the first semester of the third year and the experience took place with 184 students in the academic year 2020-2021. Until then, it had been taught in a traditional way, with theoretical lectures and practical classes for solving exercises. There were several reasons to innovate, namely the need to move to online teaching due to COVID-19, which was an opportunity to introduce new methodologies and technologies, but also the need to foster students' engagement and performance. A b-learning approach was implemented through a combination of strategies and resources, aiming to enhance motivation, interaction and participation in learning. Assessment was 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, the development of MatLab projects requires further improvements, not only as regards support to students but also the evaluation of their impact on learning.

Keywords: Innovation; B-learning; Engagement; Mathematics Education.

1 Introduction

The situation of lockdown due to the pandemic COVID-19 in the second semester of 2019/2020 forced universities to move to online teaching. At the University of Minho, teachers and students made significant efforts to adapt to this new reality and the Centre IDEA-UMinho (Centre for the Innovation and Development of Teaching and Learning - https://idea.uminho.pt/pt) had a significant role in supporting faculty through teacher training actions (see Hornink, Costa & Vieira, 2020).

In the first semester of 2020/2021, a hybrid approach to teaching was adopted across the institution: online teaching was particularly recommended for theoretical classes, and face-to-face teaching was considered to be important for practical and lab classes. The first author attended a training course where participants were challenged to plan a b-learning approach to be implemented in a course unit (CU), and she decided to innovate the CU Numerical Methods and Nonlinear Optimization (NMNO), which is part of a master's programme in Computer Engineering. The main goal of innovation was to foster students' engagement and performance by using active methodologies mediated by digital technologies and by enhancing ongoing study and progress in assessment.

The following sections focus on the context of the experience and the changes implemented in theoretical lectures and assessment procedures (section 2), the findings of the experience, based on the analysis of students' assessment results and their perceptions of the approach (section 3), and the conclusions and current developments of the experience (section 4).

2 The pedagogical experience

2.1 The context

NMNO is placed in the first semester of the third year of a master's programme in Computer Engineering that integrates the first and second cycle of studies, with a duration of 5 academic years, 10 academic semesters, 40 weeks of full-time study per year, and a total of 300 ECTS. During the programme, students acquire theoretical knowledge and practical experience regarding the analysis of software systems and the specification of those systems' requirements, the techniques for building prototypes and all the phases of their installation, the management of computer projects, the processes of testing, installation and maintenance of computer applications, and the systems or networks that support them.

The experience took place with 184 students in the first semester of the academic year 2020-2021. The CU NMNO has 5 ECTS (140 working hours) and consists of two distinct modules: Numerical Methods and Nonlinear Optimization. The learning outcomes of the UC 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. It is taught 4h a week: 2h of theoretical classes (TCs) and 2h of practical classes (PCs).

Before the pandemics, TCs were taught face-to-face in a large auditorium, with the support of slides that were made available to the students at the institutional platform (Blackboard), which can be used as a repository of lesson contents and materials. Given the high number of students in class, interaction was kept to a minimum. There were six PCs in computational laboratories with about 30 students per group. When b-learning was implemented, TCs were taught online two days a week (1h+1h) in the BlackBoard Collaborate Ultra platform, and three face-to-face PCs (2h) were carried out with about 60 students. The CU involved four teachers, but the innovation process was implemented by the first author in TCs and in assessment; PCs were kept in the same format, although one of them was taught face-to-face and online simultaneously.

Students from this programme usually like digital tools and have digital competences, therefore the use of digital technology was expected to be appropriate. However, since NMNO is not a specialized CU in the programme, in the teacher's perception, the students tend to underestimate its value and application, and it was important to change this attitude by enhancing their engagement in learning. Moreover, over the years, they felt that a lot of content was covered in tests, leading some to drop out. Changes in assessment were also needed, namely by diversifying assessment tasks and distributing them over time to foster ongoing study and progress.

2.2 Changing theoretical classes

Online TCs involved synchronous and asynchronous activities. Two virtual murals were created in Padlet (https://padlet.com) to support learning, one with general information about the CU and the other, updated weekly, providing information on all the activities related to the CU.

Synchronous activities consisted of theoretical lessons (twice a week) via Blackboard Collaborate Ultra, which were recorded to allow students to revise them or attend them in case they missed them. Before each lesson, during 10 minutes, music was played to create a relaxing atmosphere. Some lessons started with storytelling, for example about some interesting details of a mathematician's biography or real-world applications related to the CU concepts. Another strategy for introducing content was the use of appealing short videos on practical applications of the concepts taught and the resolution of exercises. Once a week, in order to verify whether the concepts were understood by the students, the Audience Response Systems (ARS) methodology was used through Voxvote (https://www.voxvote.com). A few multiple choice questions were given to the students, who were grouped in breakout rooms to analyse and decide on the correct answers, using their mobiles to respond. Then, the students and the teacher got together in the main room, discussing the student's choices and clarifying any doubts.

Asynchronous activities were mostly related to assessment, namely the development of two MatLab projects described in more detail in section 2.3. They entailed a problem-based learning approach where students had to find a real-world phenomenon for the application of a course concept. Projects were developed in teams and supervised in tutorial sessions.

Although TCs still focused on theoretical learning as a basis for PCs, there was an effort to make them more motivating and engaging. Storytelling and videos were aimed at contextualizing contents and connecting them with real-life experience. Voxvote allowed students to interact, review lesson contents, self-assess their learning and get feedback from their peers and the teacher, which was aimed at enhancing conceptual understanding and self-regulation skills (Evans, 2013). Project development was intended to connect conceptual learning with reality and enhance self-direction, cooperation, problem-solving and interdisciplinary learning, which are important elements of active learning (Graaff & Kolmos, 2003; Prince, 2004).

2.3 Changing assessment practices

Before the experience, assessment took place in the middle and at the end of the semester. Each moment included a face-to-face written test and a test on the computer using MatLab. In order to foster ongoing study and progress, assessment practices were more diversified and distributed over time. They still included two written tests done face-to-face (one per module, 50% of total assessment), but two new tasks were added: four online multiple choice mini-tests (two per module, 30% of total assessment) and two MatLab group projects (one per module, 20% of total assessment).

Mini-tests were carried out monthly with an average duration of 12 minutes. They focused on course topics through multiple choice questions (3 to 5 per test), randomly generated from extensive banks with more than 700 questions. The tests were carried out online during TCs and without the possibility of going backwards. The intention was to assess the apprehension of key-concepts and foster the student's commitment to ongoing study and timely remediation of difficulties found. Feedback was provided later by focusing on students' main difficulties.

Two MatLab projects were carried out outside the classroom in teams of four elements, chosen by the students, with the main challenge of finding a real-world phenomenon for the application of a course concept. The content of the first project focused on the Numerical Methods module and the second on Nonlinear Optimization. If the sum of the students' mechanographic numbers were even (21 teams) the course concept was Nonlinear Equations (fsolve MatLab routine), otherwise (21 teams) it was Least Squares Technique (polyfit and lsqcurvefit MatLab routines). Project development entailed connecting conceptual learning with reality and creating bridges with other scientific areas. Interdisciplinary learning is illustrated in Table 1, which summarises the scientific areas and the specific topics covered in the first project.

Table 1. Project 1 (Numerical methods)

Main Scientific area	Number of projects	Topics
Astronomy	2	orbit intersection, collisions
Biology	3	dating fossils, Escherichia coli bacteria, oxygen level in sewer
Chemistry	3	air compression factor, tank reactors in series, spherical tank with rod
Economics	4	Gold value, PIB, Bitcoin, dollar euro exchange
Electronics	2	GPS receiver, sound
Geography	3	Temperature in regions, global warming
Health	3	Covid-19
Industrial Engineering	2	profit from selling computers
Informatics	1	CPU price
Physics	9	throwing objects, impacts, pendulum, military confrontation, floating ball, missile trajectory, friction
Sociology	7	unemployment rate, birth rate per year, world population growth, condemnations for sexual abuse
Sports, others	3	American soccer, income movie

This task also aimed at developing and evaluating the MatLab practice. During its resolution, the students had several online tutorial meetings with teachers. Assessment criteria were: originality, complexity, the adequacy of computational experiments using MatLab and the quality of the final report (limited to 3 pages).

3 Findings

To evaluate the experience, two methods were used: the analysis of students' assessment results and an online survey administered in the middle of the semester to get their feedback on the approach used.

3.1 Assessment results

Out of the 184 students enrolled in the CU, 164 were assessed and only 6 failed to achieve a positive grade, which means that 96.34% passed, with grades ranging from 10 to 20 (on a 0-20 assessment scale). Out of these, only 6 had to go through a final written exam because they did not get a positive grade in continuous assessment (tests, mini-tests and projects). These results show that the new assessment methodology appears to have worked for most students. Figure 1 shows de distribution of grades.

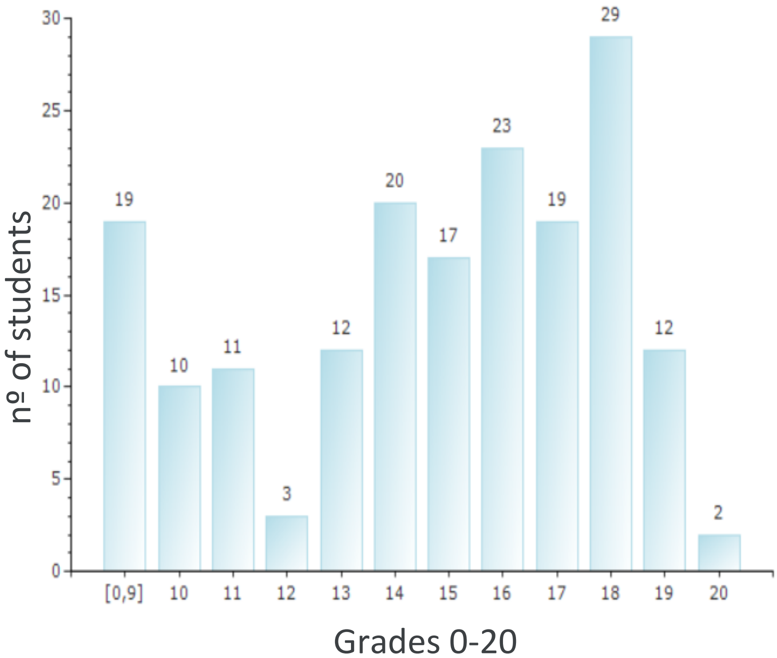

Figure 1. Students' final grades.

Mini-tests were aimed at promoting ongoing study, which appears to have been the case for most students if we look at the results in Tables 2-5. The absence rate was low, indicating their commitment to ongoing assessment, although it is still problematic that 5.4% to 12.37% missed one or more tests.

Table 2. Mini-test 1 (3 questions).

Points	15	10	5	0	absence
Students (%)	65.4	26	3	0	5.4

Table 3. Mini-test 2 (5 questions).

Points	15	12	9	6	3	0	absence
Students (%)	22.46	30.48	26.20	11.23	2.14	1.07	6.42

Table 4. Mini-test 3 (5 questions).

Points	15	12	9	6	3	0	absence
Students (%)	35.83	32.62	13.9	3.74	3.21	1.07	9.09

Table 5. Mini-test 4 (3 questions).

Points	15	10	5	0	absence
Students (%)	46.24	27.96	9.68	3.76	12.37

Projects are expected to engage students in creative and self-directed forms of learning, but that does not necessarily mean that students' grades in projects are better than their grades in written tests. A comparison was done between the grades obtained in projects and in the two written tests by the 158 students who were assessed. Project grades were better than test grades for 57 students (36.1%), and test grades were better than project grades for 101 students (63.9%).

Project grades have a 0 - 40 points range. Test grades have a 0 - 100 points range. For analysis purposes, project and test grades have been converted into a common measurement scale: 0 to 200 points. For example, a student with a 40 points project and a 100 points test (maximum grades), in this common scale, has both a 200 points project and a 200 points test. Let P_i be the grades of projects and T_i the grades of tests, with $1 \leq i \leq 158$. Let $|P_i - T_i|$ be the absolute difference between the project grade of a student and the test grade of the same student. After calculating the differences for all students, and the average of these values, the results that came up were the following.

The average difference between project grades and test grades was 38.69, the maximum gap between the project grade of a student and the grade of tests of the same student was 104.6.

These results can perhaps be explained by the complexity and unfamiliarity of project work. Despite tutorial sessions, a wide range of grades was obtained in projects, showing students' diversity regarding their ability to apply concepts to real-life phenomena and undertake self-directed learning effectively. Tests, on the other hand, focused mainly on conceptual understanding, and the use of regular mini-tests and question-answer quizzes in TCs may have prepared students to cope with them more confidently.

Project and test grades were also compared with final grades (Table 6). About 2/3 of the students (107 students) had better final grades than project grades. About 1/2 of the students (79 students) had better final grades than test grades.

Table 6. Comparison between project, test and final grades.

	better than Final Grade	worse than Final Grade	= Final Grade
Project Grade	49 (31%)	107 (67.7%)	2 (1.3%)
Test/Exam Grade	74 (46.8%)	79 (50%)	5 (3.2%)

It was concluded that when tests are taken into account, grades go up in relation to project grades. On the other hand, there is a greater balance between test grades and final grades. The following patterns were further detected:

As the grades of tests increase, the final grades also increase through an exact linear rule;

When looking for correlations between project grades and final grades, both grades tend to go up in response to one another, but this relationship is not very strong because there is a significant number of cases where this is not true.

These results are explained below in greater detail.

Let P_i be the grades of projects, T_i the grades of tests and F_i the final grades, with $1 \leq i \leq 158$. The Pearson correlation coefficient between P_i and F_i, with $1 \leq i \leq 158$, is 0.62. This means that there is a moderate positive linear relationship between the grades of projects and the final grades. While both grades tend to go up in relation to one another, the relationship is not very strong. This may be partially explained by a high variation of project grades as mentioned above. On the other hand, the correlation coefficient between tests and final grades is 1. This means that there's a perfect linear correlation between the grades of tests and the final grades: as the grades of tests increase, the final grades also increase through an exact linear rule. This seems to suggest that tests played a more prominent role in the final grades.

We also looked at other indicators such as: the gaps between the grades of tests and final grades, the gaps between project grades and final grades, and the gaps between test and project grades.

Let:

$|T_i - F_i|$ be the absolute difference between the grade of the tests of students and the final grade of the same student;

$|P_i - F_i|$ be the absolute difference between the project grade of students and the final grade of the same student;

TminusF be the average of all $|T_i - F_i|$, where $1 \leq i \leq 158$;

PminusF be the average of all $|P_i - F_i|$, where $1 \leq i \leq 158$.

Since TminusF is 10.31 and PminusF is 33.53, the average gap between final grades and project grades is almost the triple of the average gap between final grades and the grades of tests.

Let:

GP be the maximum gap between the project grade of a student and the final grade of the same student, or more exactly the maximum of all $|P_i - F_i|$, where

$1 \leq i \leq 158$;

GT be the maximum gap between the grade of the tests of a student and the final grade of the same student, or more exactly the maximum of all $|T_i - F_i|$, where

$1 \leq i \leq 158$.

Since GP is 126.6 and GT is 41, the first gap is almost the triple of the second gap. There is no significant correlation between the gaps $|P_i - F_i|$ and final grades, where $1 \leq i \leq 158$. There is also no significant correlation between the gaps $|T_i - F_i|$ and final grades, where $1 \leq i \leq 158$.

The only correlation worth mentioning is the one between the gaps $|P_i - F_i|$ and final grades when project grades are better than final grades. In this case, the correlation coefficient between the gaps $|P_i - F_i|$ and final grades is -0.6. This means that as the project grades and the final grades become further apart, final grades decrease, and as the project grades and the final grades become closer to each other, the final grades increase, although this relationship is moderate.

The analysis of students' assessment results seems to suggest that project development requires further improvements to ensure better quality outcomes for more students, which demands a closer look at students' difficulties and the enactment of better support strategies.

3.2 Students' perceptions

In the middle of the semester, in order to monitor the impact of innovation, a short Google forms survey with 5 questions was implemented (106 students answered the survey). Three closed questions focused on: the percentage synchronous classes attended by students (<25/25-50/50-75/>75); the form of attendance (synchronous/asynchronous); and the use of recorded lessons (always/sometimes/never). Two open questions were intended to gather students' opinions about what they appreciated and would like to change in the TCs.

About 85% of the students attended more than 75% of TCs, 87% of them synchronously, which is a relatively high degree of attendance given the fact that students often miss theoretical lessons. Regarding the recorded lessons, 41% always used them and 54% used them sometimes as their learning method, which appears to suggest that lesson recording may support student learning, provided that it does not discourage them to attend lessons, where they can interact directly with peers and the teacher.

Regarding the aspects appreciated by the students (Table 7), their replies were grouped according to their main focus: 'planning' (e.g., lesson organization, examples, solved exercises), 'technologies' (e.g., VoxVote and Padlet), 'methodologies' (teaching and assessment practices) and 'teacher' (the teacher's characteristics and way of teaching). A total of 258 references to these aspects were identified, showing that the approach was valued. Some students say that mini-tests allowed them to be more connected to the CU, preparing them step-by-step to the face-to-face written tests. Voxvote activities were also perceived as important to facilitate conceptual understanding and the clarification of doubts.

Table 7. Aspects appreciated by students.

Strategy	No. of references
Planning	121
Technologies	59
Methodologies	48
Teacher	30

As regards what students would like to change, two suggestions were presented: 20 students mentioned they would like to have more time to answer the questions of Voxvote, and 7 would like to solve more exercises in class. These aspects were taken into account by the teacher for the rest of the semester.

The students' perceptions in the institutional feedback survey they fill in at the end of each semester were also positive: in the pedagogical dimension, the CU was perceived to have worked in an appropriate way, with an average value of 4.7 in 5-point scale, which was higher than the average value for all the CUs at the Engineering School (3.8) and at the University of Minho (4.0). Furthermore, some students emphasized the positive and joyful environment of the lessons and a focus on learning based on interpersonal understanding and gratitude for learning, never neglecting rigor and professionalism.

4 Conclusions and current developments

The new approach fostered students' engagement and satisfaction, although assessment results were quite varied. Mini-tests and classroom quizzes through VoxVote were important to enhance ongoing study and conceptual learning, and to prepare students for written tests. However, projects appeared to demand a lot from students and there was a wide variation in their quality. 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; authentic activities which have real-world relevance, and which present a single complex task to be completed over a sustained period of time; collaborative construction of knowledge; coaching and scaffolding by peers and teachers; and authentic assessment by integrating learning and assessment into the same task. Projects also entailed interdisciplinary learning, enabling students to deal with topics from diverse scientific areas. Nevertheless, students appear to need more support for developing this type of project, especially because it is not a familiar task and it demands competences they may not possess.

The approach is being currently expanded and consolidated with other students and with institutional support from Centre IDEA-UMinho. The project was proposed to the Centre in late 2020 within a programme that supports innovative pedagogical projects. It was accepted in January 2020 and the second and third authors were allocated by the Centre as tutors. Support to the development of students' projects is one of the aspects under improvement by clarifying quality criteria, discussing them with students, giving them an example of a good project, and turning the first project into a trial activity whereby they can experience and surpass difficulties without being assessed. Other strategies to enhance the quality of projects might include forming heterogeneous groups according to students' prior competences to foster cooperative learning, and integrating problem-based and project-based learning strategies into classes. Another improvement to this experience relates to how it is evaluated. Student perceptions will be collected twice (in the beginning and at the end of the semester), and more attention will be paid to the qualitative analysis of projects as a source of evidence about students' competences and difficulties, and about the importance of projects for connecting concepts with real-life phenomena and developing interdisciplinary learning.

As teachers innovate, investigate and disseminate their own teaching practice, they engage in the scholarship of teaching and learning - SoTL (Felten, 2013; Shulman, 2004). This form of understanding and developing one's profession requires an ongoing reflective stance towards teaching and learning, along with collaboration among faculty in trying to innovate and make sense of experience. The programme of Centre IDEA-UMinho provides an opportunity for enhancing SoTL with the support of faculty mentors who act as critical friends, which surely helps to improve pedagogy in a collaborative and sustainable way.

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Mapping the circular economy context within the curricula in the field of Industrial Engineering - comparative study of degree programs in two Polish universities

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Abstract

Streamlining the circular economy (CE) topic across the industries has significant mobilizing effect on academic curricula. New programs, new courses and its topics are being introduced in order to provide knowledge and skills that are appropriate to handle circularity challenge. The objective of the paper is to investigate the issue from the perspective of Industrial Engineering field of knowledge and academic programs. The objective of the paper is to develop the framework to compare the coverage for CE related issues, and subsequently to verify it within the degree programs of two Polish universities: Cracow University of Economics (CUE) and Częstochowa University of Technology (CUT). The comparison is based on the content of the following building blocks of curricula: objectives, program learning outcomes, graduate profile description, courses and course learning outcomes. The group of programs included within the analysis consists of the ones that are tightly related to Industrial Engineering but are defined individually by the Universities. The bachelor programs of Quality and Production Management (CUT) and Management and Production Engineering (CUE) are in the core of comparison. The comparison aims also in mapping the CE related skills and competences within compared programs.

Keywords: Circular Economy; Industrial Engineering; Industrial Engineering Degree Programs; Circular Economy Education.

1 Introduction

1.1 Circular Economy concept and its building blocks

The circular economy (CE) concept has gained increasing attention from global policymakers, which has also turned into more in-depth definition of the concept and underlying mechanism. Despite the common engagement of regulators and scientist the features of CE or its implementation conditions and requirements are yet not clearly defined.

The most widespread definition of CE is that published by Ellen MacArthur Foundation, where CE is defined as „an industrial system that is restorative or regenerative by intention and design. It replaces the ‘end-of-life’ concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models“ (EMF, 2013).

Kirchherr et al. (2017), after distilling from over one hundred of definitions, defined CE as: an “economic system that is based on business models which replace the ‘end-of-life’ concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations”. Murray et al. (2017) has defined CE as “an economic model wherein planning, resourcing, procurement, production and reprocessing are designed and managed, as both process and output, to maximize ecosystem functioning and human well-being”. Since our approach is based on referring CE concept to the fields of knowledge in higher education, it is important to summarize these definitions from the perspective of its contributing fields and building blocks. These fundamental building blocks of CE in Europe are grouped under eight headlines as (1) industrial symbiosis, 2) material resource efficiency, 3) product life-cycle extension, 4) biological products, 5) energy efficiency and renewable energy, 6) the performance economy, 7) the sharing economy and 8) the platform economy (Taranic, Behrens, & Topi, 2016).

As proposed by Circle Economy organization the core elements of CE transition are: prioritize regenerative resources, stretch the lifetime and use waste as a resource. The key enablers to achieve that are named as: rethink the business model, team up to create joint value, design for the future, incorporate digital technology and strengthen & advance knowledge (Goodwin Brown et al., 2021).

1.2 Referring CE to the field of knowledge

According to Türkeli et al. (2018) CE research is originating from the following fields of knowledge: Environmental Sciences, Environmental Engineering, Energy & Fuels, Management, Geography and Urban Studies, Economics, Industrial Engineering, Manufacturing Engineering, Thermodynamics, Chemical Engineering, Biotechnology, Agricultural Engineering, Water Resources. The classification of fields of knowledge to the specific building blocks of CE concept is presented in Table 1.

Table 1. Coverage of CE building blocks within fields of knowledge

Building blocks of CE	Major fields of knowledge	Minor fields of knowledge
industrial symbiosis	Environmental Engineering Industrial Engineering Manufacturing Engineering	Environmental Sciences Energy & Fuels Management Geography and Urban Studies Chemical Engineering Biotechnology Agricultural Engineering
material resource efficiency	Environmental Engineering Manufacturing Engineering	Energy & Fuels Industrial Engineering Thermodynamics Chemical Engineering Agricultural Engineering Water Resources
product life-cycle extension	Industrial Engineering	Management Manufacturing Engineering
biological products	Environmental Sciences Biotechnology Agricultural Engineering	Environmental Engineering Chemical Engineering Water Resources
energy efficiency and renewable energy	Energy & Fuels Thermodynamics	Environmental Engineering Industrial Engineering Chemical Engineering Biotechnology Agricultural Engineering

		Water Resources
performance economy	Management Economics	Energy & Fuels Industrial Engineering Manufacturing Engineering Agricultural Engineering
sharing economy	Economics	Management Geography and Urban Studies
platform economy	Management	Economics

The objective of the paper is to propose an assessment framework to investigate the issue from the perspective of Industrial Engineering field of knowledge and academic programs. Since, no such methods or studies has been proposed so far, the paper is aiming at signalizing the coverage of CE concept within existing academic programs with a proposed mapping approach. The objective of the paper is supported through the comparison of the degree and master programs of two Polish universities: Cracow University of Economics (CUE) and Częstochowa University of Technology (CUT). The assessment and comparison method is based on the content of the following building blocks of curricula: objectives, program learning outcomes (PLOs), graduate profile description, courses and course learning outcomes (CLOs).

2 Mapping CE context within selected programs

2.1 Characteristics of the investigated programs

According to the Türkeli et al. (2018) industrial engineering (IE) is one of the fields of knowledge that addresses the issue of CE and its application. The programs that are selected for comparison are Management and Production Engineering (CUE) (UEK, 2021) and Quality and Production Management (CUT) (CUT, 2017). According to the classification prosed by Lima et al. (2012) both of this programs belong to IE field of knowledge but at the same time at its core the fields of management and manufacturing engineering are also covered (Nitkiewicz et al., 2020). Therefore, both of the programs should be providing graduates with appropriate competences to deal with managerial and IE aspects of CE solution implementation. The two programs are considered from the perspective of CE concept and its underlying building blocks. The basic characteristics of the two selected programs is presented in Table 2.

Table 2. The comparison of basic characteristics of the two selected degree programs

Characteristics	Management and Production Engineering CUE	Quality and Production Management CUT
Level	Degree program (engineer)	Degree program (engineer)
No. of Years / Semesters	3,5 / 7	3,5 / 7
No. of ECTS*	221	210
No. of Course Hours (contact hours)	2100	2404
No. of Courses**	47	68
No. of PLOs (Knowledge/Competences/Social skills)	5/7/5	10/11/5

** European Credit Transfer System (ECTS) - is a standardised credit system of the European Higher Education Area for better recognition of students' academic qualifications and study programs and possible exchange periods abroad

* refers to number of courses, both obligatory and electable, required finish the degree

According to ECTS a degree program consists of either 180 or 240 credits for 3 or 4 years programs, respectively. Since both of the programs considered are 3,5 years long the nominal ECTS credits ceiling is 210, but with MPE program it is excessed with additional courses. As indicated in the Table 2, the PLOs are divided into three categories: knowledge, competences and social skills. In general, social skills should be out of the scope of CE related education and competence building, since they are universal and indifferent concerning the scope of its application.

The objectives of the curricula, as stated within program documentation, does not refer directly to CE concept, but mention several fields of education that are related to CE (mostly the field of industrial engineering and management, as well as its elements). It seems that CE concept at its complexity is not addressed intentionally neither in QPM nor in MPE curriculum. Similar case is for graduate profiles that are referred to the industrial fields and set of competences appropriate for CE implementation in both investigated curricula.

2.2 Mapping CE context within PLOs of selected programs

The comparative analysis of PLOs is based on CE specific criteria that are divided into direct and indirect category. The elements belonging to these categories are further classified with regard to their reference to CE concept. The methodology of classification is presented on Figure 2. By direct reference we mean the use of CE concept itself or its building blocks in an element of curriculum. By indirect reference we mean the use of term that could be underlying prerequisite or necessary condition for the CE concept or its building blocks implementation. The distinction between the content and approach alignment to CE is made upon the way curriculum elements are presented. CE content is generally covering its building blocks while CE approach is matched with CE enablers. The symbols used to denote the reference on Figure 2 are composed of the part indicating its type (CA – content and approach; C – content; A – approach) and the part indicating its strength of CE concept support with the scale of 1 to 5, where 1 indicates the highest possible contribution to CE knowledge and skill set, while 5 indicates the lowest possible, but still contributing factors.

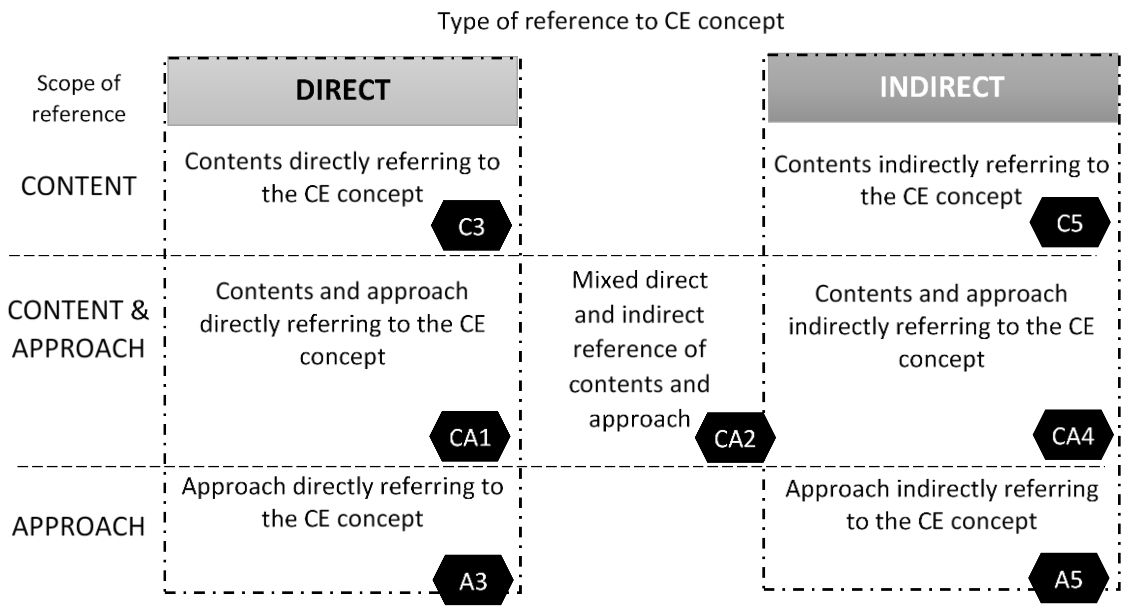

Figure 2. Type of reference of academic programs to CE concept

Figure 3 and Figure 4 map the relationship of PLOs of investigated degree programs to CE concept. The denotation used here refers to three different types of learning outcomes: knowledge (denoted as W), competences (U) and social skills (K). The PLOs are numbered according to their appearance order in program documentations. The map is based on the criteria presented in Figure 2. According to the classification, each PLO is qualified to the category of content, approach or content and approach reference, which is in the following step assessed with regard to its directness towards CE. The size of the bubbles is representing the significance of given PLO for the whole program. This is measured by the number of references to given PLO in course syllabuses. The more references the better coverage for given PLO within the program.

To get an overview of the PLOs that are highly contributing to CE education two of them that are classified as the most significant in a sense of its contribution are presented below:

Student has basic knowledge to understand mutual influence of phenomena and processes of economic, legal, organizational and engineering character that occur in companies

[PLO W02 from QPM (CUT)]

Students knows and understands the processes occurring in life cycle of machines, objects and technical systems. Additionally, student has knowledge on materials, technologies and tools used for solving engineering type of problems related to Management and Production Engineering field of knowledge

[PLO W04 from MPE (CUE)]

The content issues within the two PLOs is related to industrial processes (W02 QPM) and necessary equipment and infrastructure to run them (W04 MPE). The approach that is appropriate to CE concept is presented by interrelation of "*economic, legal, organizational and engineering character*" (W02 QPM) and life cycle approach (W04 MPE).

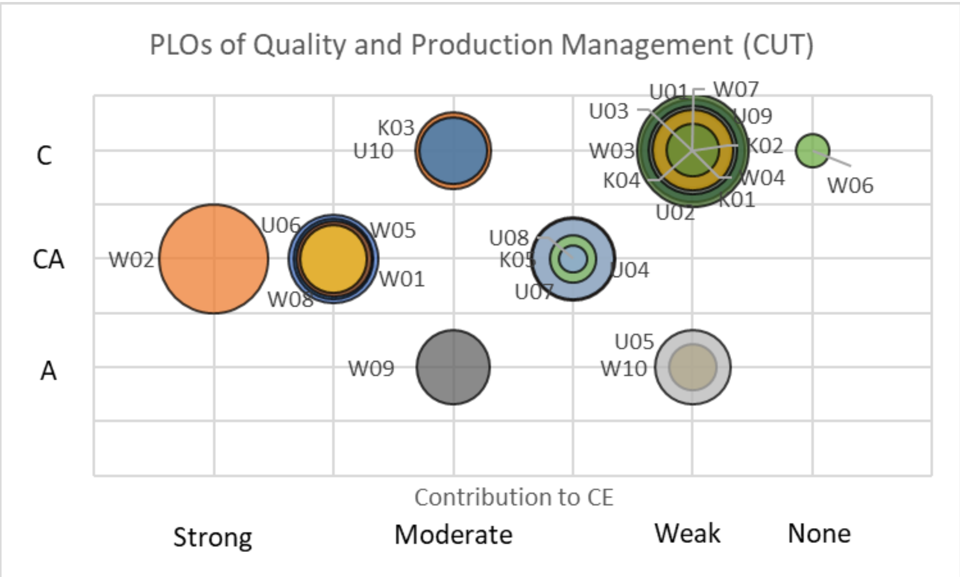

Figure 3. The reference of PLOs to the CE concept: program of Quality and Production Management (CUT)

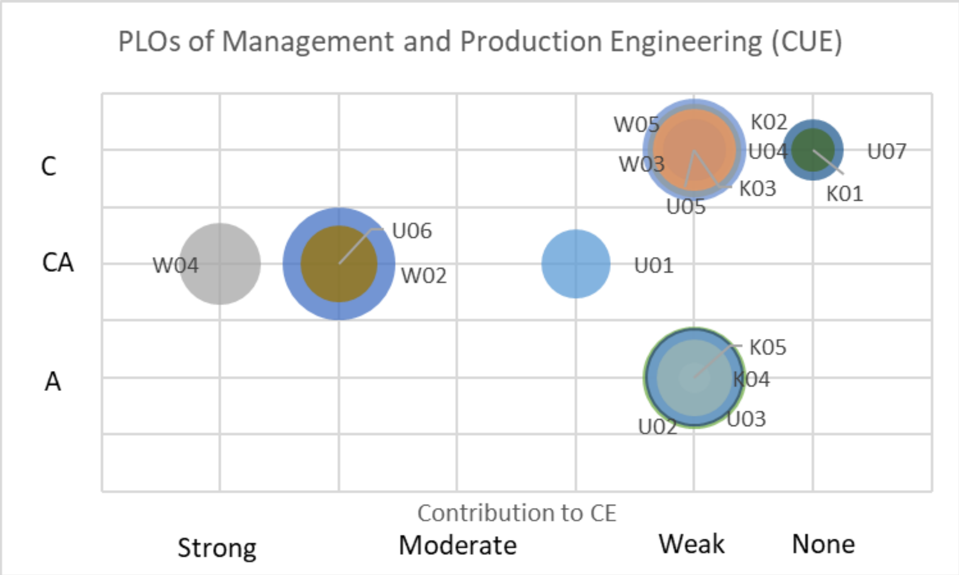

Figure 4. The reference of PLOs to the CE concept: program of Management and Production Engineering (CUE)

While interpreting maps on Figure 3 and Figure 4 we should also spot the strong contribution of CA PLOs within both programs. These groups consist of W02 and U06 and W01, W05, W08 and U06 for MPE and QPM programs, respectively. The direct support for CE related knowledge and skills is more developed within QPM programs with a set of C (U10 and K03) and A (W09) PLOs. The remaining group of PLOs could only slightly contribute to CE competence and knowledge building or have no significant impact at all.

The mapping framework developed here shows a potential to assess and compare the programs with regard to its CE preparedness capacity. On the other hand, the use of ordinal classification parameters leads to the clustering of PLOs and, in a consequence, difficulties in detailed interpretation of the data. The transformation of ordinal parameters to continuous variables could bring the important breakthrough in reading the data.

2.3 Mapping the CE context within course structure and CLOs

The following step of analysis is related to the courses included in the two analyzed programs. From the perspective of the potential contribution to CE concept the courses has been classified as related, potentially related and unrelated ones. Table 1 presents the results of courses classification and includes three classification levels and considers courses specific for both of selected programs as well as courses that are common for both of them. In the case of the courses with the same names it is just written in appropriate cell of QPM & MPE row. In case of the courses with supposedly same content but different names it is denoted with the slash symbol ("/"). Occurrence of "&" symbol indicates the two courses that fit together to the topic of one course form another program. Both programs have the similar number of courses that are classified as directly related to CE concept. Three out of these courses are the same or very similar within both programs. These courses cover environmental management, waste management and logistics issues. QPM CUT program has also course on sustainable management and on process and product innovation that are classified as directly related. MPE CUE program has also course on biotechnology, on production system design and on cleaner production.

Table 1. Classification of courses with regard to their relationship to CE concept

Programs	**Courses**		
	Directly related	**Potentially related**	**Unrelated**
QPM	Sustainable management Process and product innovation	Materials in production processes Operational research investment projects Intelligent SMART Metering system Theory of machines Safety of process installations	Industrial property management Statistics in production Sociology Negotiation and mediation techniques Production scheduling and control

		ERP Management support system Lean Manufacturing Documentation of quality and work safety systems Quality control in special processes Computer simulation of manufacturing processes Management of machinery and equipment operation Engineering project Transport infrastructure management Energy efficiency management Production systems Commodity science Virtual enterprises	Statistical process control Ergonomics Six sigma Technological resources
QPE & MPE	Environmental management system / Ecology of natural resources and environmental management Industrial waste management / Waste Management Production Logistics / Corporate Logistics	Business-to business-marketing / Marketing Economic law / Business Law Macroeconomics Production processes and technologies Microeconomics Production and service management Quality management & Work safety management / Quality and Safety Management Introduction to automation of production processes / Automation of production processes Engineering project management Fundamentals of engineering design / Machine Construction and Engineering Designing Computer support for engineering projects / IT and Computer-Aided Methods for Engineering Work	Accounting for manufacturing companies & The Cost Account for Engineers / Accounting Mathematics Physics Finance Business management basic Information technology Fundamentals of metrology / Metrology Engineering and technical drawing / Engineering Graphics Physical Education Methods of business organization and management / Basics of Organization and Management Human Resources Management
MPE	Biotechnology Production System Designing The Technologies and Organization of Cleaner Production	Chemistry Business ethics The Knowledge of Materials and Light Industrial Engineering The Knowledge of Materials and Plastics Engineering Vegetable Food Processing Processing Food of Animal Origin Packaging techniques Microbiological Industrial Threats Operational Management	Physics The Protection of Intellectual Property The Basics of Mechanics and Strength of Materials Statistics

The last part of the analysis refers to the objectives and learning outcomes of the courses that are supposedly related to CE concept. The classification is presented in Table 2. The classification of contents is based of the ratio of teaching hours that are related to CE concept and its underlying building blocks. The classification of course objective (CO) and course learning outcomes (CLOs) is based on the same assumptions as the one used for PLOs. As shown in Table 2 the direct, not all of the courses maintain to keep the direct link to CE concept (examples of *Process and product innovation* and *Logistics* courses) or keep it only through the content and not the approach (*Production system design*). Not surprisingly, environmental management and waste management courses have the highest capacity and best coverage to contribute to CE related knowledge and skills. The significance of *Sustainable management* course is somehow undermined by its electable character, nevertheless, it is has the third highest contribution.

Table 2. Classification of objectives and learning outcomes of selected courses from QPM and MPE programs

Courses with direct connection to CE concept	**QPM**		**MPE**	
	Contents	**CO & CLOs**	**Contents**	**CO & CLOs**
Sustainable management	80,0%	CA2		
Process and product innovation	30,0%	CA4		
Environmental management system / Ecology of natural resources and environmental management	95,8%	CA1	87,0%	CA1
Industrial waste management / Waste Management	93,3%	CA1	100,0%	CA1
Production Logistics / Corporate Logistics	42,9%	CA4	33,3%	CA4
Biotechnology			26,7%	CA2
Production System Designing			37,5%	C3
The Technologies and Organization of Cleaner Production			65,2%	CA2

The approach used for mapping the course structure with regard to the CE context is still missing the aggregation functionality that would enable the complex comparison of the programs. For the moment, the mapping approach proposed is applied to assess PLOs and course structure independently. The next step in its development, and perhaps in wider assessment of industrial engineering programs, is to develop its results synthetizing mechanism and easy-to-use framework for curriculum development and adjustment to CE requirements.

3 Conclusions

As the results of analysis shows, the industrial engineering programs, namely Management and Production Engineering at CUE and Quality and Production Management at CUT, have strong relationship to CE concept but it should be still classified as secondary type of relationship. This is due to relatively weak coverage within PLOs and courses. Some courses are strongly dedicated to CE related content and have pretty wide coverage for CE building blocks. CE concept is not addressed literally, neither within the objectives and PLOs of the programs, nor within dedicated courses.

Since CE plays key roles for industrial economics to pursue sustainable development, it should be indeed acknowledged as capable of harmonizing ambitions favoring not only economic growth but also environmental protection, thereby opposing to the conventional highly-impacting linear model of the economy (Hysa, Kruja, Rehman, & Laurenti, 2020). Such a transformation should be also happening at the level of higher education within industrial engineering and its related fields. The investigated programs have been visibly equipped with toolbox needed to introduce CE solutions but still in non-systemic and partial way. Nevertheless, the key building blocks of CE have significant coverage and potential for further development.

The approach used here for mapping CE content within the degree programs within industrial engineering knowledge area has some limitations. First of all, the mapping process was not referred to the CE benchmark since there is no clear consensus on CE education within IE field. Secondly, the mapping was performed upon the documentation of the two programs and, therefore, had no reference to the students or industry preferences, evaluation of graduates or opinions of academics. This drawback could be easily overcome with completing the study with additional steps but since QPM curriculum has not yet produced its graduates it was not possible at the time of writing the paper.

The assessment and mapping framework is not yet finalized, and as mentioned above, has some significant drawbacks related to the subjectivity of the assessment, lack of results integration functionality and dependance on ordinal variables. The proposed framework should be a starting point of the discussion on introducing CE learning outcomes in industrial engineering programmes and the assessment of its progress methodology.

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An innovative approach to computer mathematics teaching in a large engineering class

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Abstract

This work describes the changes in a CU (curricular unit), Numerical Methods, that occurs in the second semester of the second year in the master’s programme of mechanical engineering, in 2020-2021. The methodology used in this CU was obsolete and has been taught with expositive classes and practical classes with little participation of the students. The big challenges are the dimension of the class (112 students), the lack of motivation to the subject of the CU and the fact that the CU appears very early in the teaching programme. This turned out to be even harder with the migration to online teaching, due to the pandemic and the uncertainty of the remaining of the semester (at this point we still don’t know if a blended learning system is going to be possible). The CU is working with some technological resources such as padlet, PollEv, BlackBoard and Ted Ed. The strategies being implemented are Problem-Based Learning (PBL), Audience Response Systems (ARS) and it has been used a partial flipped classroom strategy. Every week there are small videos available, to introduce the subjects and engage the students, and other videos are recorded in the Blackboard platform during the more expositive and complex parts of the classes, as well as exercises (by hand or in MATLAB™). In terms of assessment, there are weekly mini-tests, some of them in MATLAB™, preceded by a preparation quiz in the platform PollEv in a session before the class to maintain the students’ engagement. There is a small project in MATLAB™ where the students in teams are encouraged to search for an applied problem from the real world in the suggested routine. There are two planned face-to-face tests, one of them already took place. In the practical classes, the students are divided in smaller classes, where they can practice with the teacher (these classes had now migrated to a face-to-face scenario). The results until this point are very promising, with a wide participation of the students and excellent scores in the mini-tests.

Keywords: Active Learning; Engineering Education; Problem-Based Learning (PBL); Audience Response System (ARS)

1 Introduction

According to the assumptions raised in the literature, this article aims to present a report of experiences about the realization of the perspective of learning mathematics as a "process of individual construction and as a process of acculturation in relation to the mathematical meanings and practices" in a given social environment. These experiences were carried out in the context of Engineering Education, in a curricular unit (CU) of the mathematics area, namely Numerical Methods, which took place in the second semester of the second year in the master's program of Mechanical Engineering, in the second semester of the academic year 2020-2021.

The remainder of this paper is organised as follows. In section 2 is presented the theoretical background for systematization of the concepts that support the educational methodologies adopted. In section 3 is made a contextualization to the actual problem. Section 4 presents the learning methodologies, strategies and assessment methods adopted and in section 5 some preliminary results are presented. The paper is finished with some recommendations and final remarks in Section 6.

2 Theoretical Background

Khait (2005) states that in recent years, the mathematics-related competences needed for the demands of work have become increasingly associated with computerization and information saturation in the social environment. The "de-mathematization" of society has occurred through the transfer of traditional roles from mathematical professionals to calculators and computers. However, the demands for cognitive skills related to mathematics have grown because of the need to behave appropriately in today's technologically sophisticated environment. For Khait (2005), the need for the development of mathematical language competences has become more urgent in the context of the computer revolution. The ubiquity of computer applications and human-machine interaction increase the importance of mathematics education for modern society. In this context, the competent worker in high-tech industries is the one who is able to construct new definitions and understand the definitions constructed by their colleagues, and the job of an information technology professional is to make the transition between formal (human-machine) and informal (human-human) communication.

In this context, researchers and agents responsible for mathematics education have made important reflections about their performance and about students' behaviour. Boaler (1999) draws attention to the fact that students not only develop a behaviour, but a behaviour that is appropriate to a particular community that constitutes the classroom. He considers the following behaviours to be the most common in classrooms: (i) when students must solve exercises, they expect that using the methods they have learned on the blackboard is the appropriate procedure; (ii) if a question requires knowledge of the real world, or knowledge unrelated to mathematics, students consider that they should stop and ask for help; (iii) students always expect to use all the content they have studied on the blackboard, or all the symbols in a diagram, and so on. According to this author, when students encounter situations in textbooks that do not fit their expectations in terms of behaviour, they become confused, not because they do not understand the mathematical issues involved in the questions, but because they are not used to deal with situations that do not follow a dynamic of reproduction and classification. They rarely select the information they need, but always expect that they must apply exactly the procedures they have learned on the blackboard. He further reports that the alignment that students make between requirements and possibilities in mathematics classes also has major implications for their real-world use of mathematics. Students often report that in their day-to-day jobs they face completely different challenges than they do in the classroom.

Khait (2005) considers that there are different educational perspectives on mathematics, among which the most common are, (1) the one that is based on the view that mathematics deals with subjects that can be objects of an exact theory, thus corresponding to a set of rules that must be applied to solve problems, and (2) the approach that treats mathematics as a language and a way of thinking, thus that it is a method whose boundaries adapt according to circumstances. The latter interpretation implies that what makes a word or an expression belong to mathematics is not its exact meaning, but the way in which this meaning is perceived. In this respect, mathematics should be understood as correctable, fallible, and socially changeable.

According to Cobb *et al*. (1992), learning mathematics can be seen as a process of individual construction and acculturation in relation to the mathematical meanings and practices of a certain society. Since the teacher is the only member of the constituted classroom community who evaluates the students' construction process as a potential basis for learning, it is therefore incumbent upon the teacher to facilitate discussions around mathematics among students while acting as a participant who legitimates certain aspects of mathematical activity and sanctions others. In this way, the teacher acts directly on each student's constraints on the interpretations and solutions of mathematical challenges, in a context of communication that involves the explicit negotiation of mathematical meanings.

Thus, we can summarize from Boaler (1999), that theories of Mathematics Education initially focused attention on individuals and on mathematics in order to advocate the repetition of mathematical behaviours and later on the construction of knowledge with the individual as the central element. For the author, these perspectives suggest that students' behaviours and practices in situations involving mathematics are not just mathematical, nor are they individual, but are emergent from a relationship formed by people and systems.

For Khait (2005), in opposition to the Platonic and formalistic point of view, mathematics should be understood as a human activity, a social phenomenon, part of culture, historically involved and intelligible only in the social context. The author points out that what maintains the unity of a scientific community does not need to be a set of beliefs. In fact, the sharing of beliefs is far less common than the sharing of practices, precisely because the sharing of practices depends on the sharing of beliefs, not the other way around.

Malloy & Malloy (1998) say that culture is the sharing of meanings, but not necessarily of consensus. Therefore, culture is values and beliefs that are embedded in the way people in a community think and act, and in the tools they use. In the past, educational environments were thought of in a way that made differences difficult. The term used to describe the ability to adjust to new cultures is "adaptation," and the authors believe that students must develop this ability and practice it in the various cultures that identify classrooms and disciplines, so if the environment does not yet provide for the coexistence of differences, it must change.

Schubring (2011) mentions the "humanization of mathematics," a very present thought in research on mathematics education in recent history, a goal pursued by many who are dedicated to finding ways to turn this idea into a concrete reality.

For Boaler (1999), the effectiveness of a classroom community involves the adherence of the educational environment and the rules of mathematics to the interpretation of non-mathematical issues and the suppression of certain attitudes. Students should be encouraged to develop independence over their actions and over their paces of action. Instead of the quantity of mathematical experiences and the requirement for repetition, the quality of these experiences should be observed and students should be helped to engage in finding skills to deal with them collaboratively in interpersonal activities. Thus, the author considers that a number of strategies unrelated to learning contribute to success in the classroom since in this environment students not only learn mathematical concepts and procedures, but also learn to interact, and to develop a set of beliefs and ways of proceeding, appropriate to behaviour in the face of mathematical challenges.

For Malloy & Malloy (1998), traditionally, mathematics, as an academic subject, may be at the level of algorithms to be reproduced and procedures to be followed. Even there, the prospect of a culture of mathematical thinking may be present, however, only those who demonstrate a superior understanding of that culture are chosen to receive some sort of mentoring, development, enrichment activities, opportunities for exploration, and access to more advanced mathematical problems. Others who demonstrate limitations are relegated to performing a script of mathematical practices that do not necessarily signify learning, much less inclusion in the mathematical culture.

Malloy & Malloy (1998) consider that the social, cultural, and historical context in which students live define and format their experiences. The personal and knowledge culture may conflict with the scientific way of validating knowledge, and when related to mathematics learning, it impacts the students' self-perception as members of a mathematics community. Therefore, for the authors, what defines the inclusion or exclusion of members to this community are three factors: screening, impersonal conditions, and language. In this context, students' success in class depends on their ability to understand and participate in the culture of those in power, since in a way the academic environment reproduces the culture of society at large in structure, rules, and hegemony. Therefore, Malloy & Malloy (1998) argue that the classroom atmosphere should provide opportunities for students to experience mathematics socially by confronting appropriate levels of challenge, meaningful goals, opportunities for risk-taking, and a variety of strategies so that they overcome obstacles through the use of mathematics communication in a classroom designed with a strategy that values variation in organization and a pedagogy that offers students the possibility of adjusting to diverse learning styles, such as holistic perspective, free thinking, and others. Students should be encouraged to seek a big picture view, to improvise and use intuitive thinking, to verbalize their ideas, and to engage them in social interaction with discussions, independent goal construction, and their own pathways for knowledge expression.

Tawfik & Lilly (2015) stress that the main goal of education is to prepare students to construct solutions in a given domain of practice to overcome authentic problems. Therefore, it is important that students have contact with challenges, constraints and perspectives that practitioners experience. The authors believe that this pedagogical approach allows students to take ownership of knowledge and its construction process in a way that enables them to adopt an active role in the educational experience. One way to facilitate this educational strategy is through the engendering of self-learning skills supported by learning technologies.

Tawfik & Lilly (2015) present the so-called "flipped classroom" methodology that has these attributes. According to DeLozier & Rhodes (2017), flipped classroom is a teaching method in which the classroom organization logic is inverted so that the consumption of content takes place in advance, through online learning, and the classroom meetings are dedicated to interaction, clarification of doubts, group activities, and others. Thus, flipped classroom is so named precisely because it subverts the traditional model of teaching and learning. In the latter, the content is consumed in the classroom and the activities must be performed at home. In the proposed model this dynamic is inverted. The content must be studied at home and the classroom must be the space for interaction and exercises. In this case, the teacher is a mediator of effective learning practices. The most recommended practice for teachers is to record lectures in short videos or other multimedia resources that can be made available to students online.

According Tawfik & Lilly (2015), the flipped classroom model applied in conjunction with other resources such as Problem Based Learning (PBL) can provide a just-in-time basis for learning in a way that engages students effectively in finding solutions to real or similar problems that are common in real life. For these authors a key element of PBL is structured problems that have multiple constraints, can be observed from different perspectives, and provide multiple potential solutions. This approach focuses on authentic contexts and postulates that learning should be experience-based and situated within a domain. Thus, students take an active role in the learning process, use technologies that enable autonomy, develop knowledge construction through elementary guided inquiry, experience real-world problem solving, and interact collaboratively to reach creative solutions.

For DeLozier & Rhodes (2017) the flipped classroom is a student-centred education method, that is, the students are responsible for studying the content by themselves and the face-to-face meetings should be opportunities for discussion, which also does not take away the student's protagonism. This discussion can be carried out in various ways, such as audience response, open questions, individual or paired quizzes, pair and share activities, student presentations. The authors state that prior study of the content can be accomplished through videotaped lectures by the teachers.

3 Context

This experiment took place with a class of 112 students of Mechanical Engineering. The Curricular Unit (CU) is Numerical Methods and occurs in the second curricular year of this master's programme. This CU consists in advanced mathematics and appears too soon in the course, which is an added difficulty, due to the maturity of the students at this stage of the course. The ideal would be that this CU appeared at least in the third year of the course.

The classes occurred in a traditional and obsolete context until now. The quick emerging of the online classes due to the pandemic appeared as an opportunity to modernize the CU and implement some new methodologies to motivate the students for a CU that typically they don't like, because it is difficult and it is not specific to theirs course. At the middle of last year's second semester a quick migration to online classes obliged to implement some different strategies, that are being pursued this year. All of these methodologies are easily transferred for the presential context, that will occur predictably in the last third of the semester.

4 Learning methodologies, strategies and assessment methods

4.1 Availability of materials

The important informations and materials about the classes are in a padlet. This includes the presentation of the professors in the team, curricular program of the CU, recommended bibliography, overall planification, problems to solve (by hand or in MATLAB™), mini-projects to each group, assessment details and links to the tools used in the classes, such as instructions to use MATLAB™ online, TED-Ed, PollEverywhere, and Blackboard. This padlet can be found in https://padlet.com/isabelpinhoespiritosanto/jqg4q5kvq3tiuf4y.

There is a second padlet, where the students can find the planning and more detailed instructions to each week, working as a road map to the classes and study. It contains, among other things, the slides used in the expositive part of the cases, the solutions to the proposed problems each week and the videos (of the expositive part of the classes, resolution of exercises and problems solved with MATLAB™). As a complement, each week is offered a music that is contextualized with each class and environment lived at the moment with the pandemic, to help to give a more embracing, broader and more human point of view to the subjects usually approached in the CU. This padlet can be accessed in https://padlet.com/isabelpinhoespiritosanto/Bookmarks.

4.2 Flipped Classroom

It was introduced a kind of hybrid flipped classroom to engage the students in the resolution of the problems. The subject is complex and they need some help to understand the basic theoretical concepts. Some introductory and simple videos were provided the week previous to the class, as well as the pages from the support text that they should study. The first synchronous weekly moment, that occurs on Mondays with the entire class, is devoted to a brief exposure of the more important theoretical concepts, to consolidate the videos and text they were proposed to prepare ahead of the class. It is presented as well a practical example solved with the presented algorithm, and using the adequate MATLAB™ routine. This way the students may interfere and question the parts that they don't understand and sometimes they can share with each other their perceptions. These classes are always recorded, so the students can return to them latter if they need to. The second class (face-to-face since 19th of April), was devoted to solve practical exercises, introducing a PBL methodology. A problem is proposed, in the subject at hand, and the students have to solve it, alone or in groups, discussing the results among them. The teacher is essentially a moderator, pointing the right direction, giving suggestions and sometimes helping to correct some mistakes. This was more effective in the face-to-face context, but in the online classes it was asked to the students to speak and sometimes ARS were used to facilitate the communication.

4.3 Audience Response Systems

The most difficult thing in the online classes is to have feedback from the students. Usually, I have 100 black squares in total silence. The way I found to turn this issue around was implementing ARSs. A simple question like "did you all understand?" was inevitably followed by total silence. I do the same question but in a quick quiz in the Blackboard with two possible answers: yes/no. It is amazing the change that this simple practice brought to the classes. I can assess if it is necessary to dig deeper into the issue at hand until there are only yesses. The students are divided in three different practical classes, that occur on Thursdays, where they can dialogue with the teacher to explore and solve exercises. To incentivise the participation of the students, an Audience Response System (ARS) is also implemented (the PollEv platform). This way, the students are invited to share their results in an anonymous way. According to the answers some are invited to share their conclusions with the colleagues. There are also facultative sessions where the students may again practice and ask questions to the teacher and to each other. The teacher mediates these sessions also with PollEv.

4.4 Assessment

This is probably the bigger change in the CU. Traditionally the students used to have only a written test (15/20) and a MATLAB™ test (5/20). The online assessment brought difficulties, that were also a huge opportunity to improve the assessment methodology, maintaining the equity and fairness to all of the students.

The main idea was to divide part of the assessment (6/20) into 8 small mini-tests of 5/6 questions of multiple choice (4 possible answers) during 10 minutes, before each class. This works as formative tests more than a summative evaluation. It is assumed that the students talk between them, since they are at home, but the effect in terms of scores is negligible and they learn either way, which is the most important issue at this point. Also, each of the 5 questions in a mini-test has 20 versions of equivalent degree of difficulty, and the test is generated randomly, giving rise to 20^5 (3,200,000) different possible tests. Also, the order of the questions is random, as well as the order of the possible answers. The probability of a student to have success in a test (considering success achieving 3 or more questions correct) is only 1.56%, and when considering all of the 8 mini-tests it drops to only 0.06%, using a binomial distribution.

The MATLAB™ assessment is made with 4 mini-tests (4/20) and also with a group project of 4 students (4/20). They are divided into 4 themes and are invited to find a real-world problem that fits that specific theme, solve the problem using the software and write a small report about the problem itself, the technique used to solve it and the conclusions they take from it. The themes explored were non-linear equations and systems, function approximation, numerical integration and differential equations. The students present essentially problems from the mechanical engineering context. This way they can see the applicability of what they are learning in a more real context, giving rise to much more motivation, that was observed in the students that had already finished theirs projects. All of the above implied 63 banks of tests with 20 questions each (1260 questions in total), that were prepared and implemented in Blackboard, only for the online assessments.

Finally, they had 2 face-to-face assessment moments (6/20).

5 Results

Since the CU is still, these results are only preliminary. It was implemented an intermediate quiz to evaluate the student's satisfaction with the implemented changes.

5.1 Attendance to the classes

It was noticed a much higher presence of the students in the synchronous classes, as it can be confirmed in Figure 1 by the students' responses and as it was observed by the teachers. This is a great challenge because in this stage of the semester all the classes are online, and the main parts were recorded and made available latter, which could lead to a lower attendance. This was not observed at all. The students understood perfectly the advantage of the synchronous moments to clarify aspects that can be more challenging, and to solve problems in the presence of the teachers, to ask for help if needed. Also, they have the possibility to assist to the classes latter (Figure 2), since they were recorded. To have a comparison basis, Table 1 shows the difference in classes attendance, also compared with the previous 2 academic years, in percentage.

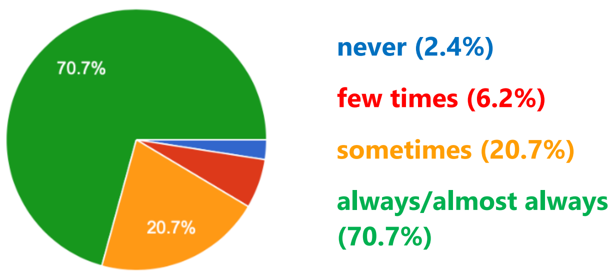

Figure 1. Attendance to the online classes.

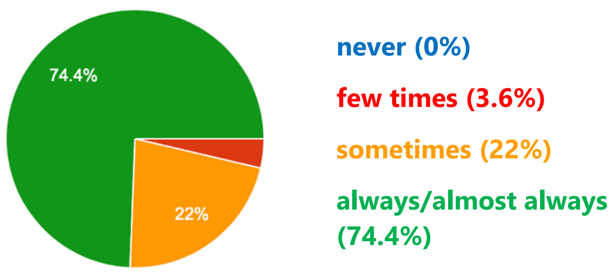

Figure 2. Use of the online classes recording.

Table 1. Comparison of the attendance to the classes in the last 3 academic years.

	2020/2021	2019/2020	2018/2019
Always/almost always	70,7	47,7	55,6
Sometimes	20,7	25,5	35,6
Few times	6,2	4,8	6,7
Never	2,4	2,4	2,2

Figure 3 shows how much the students use the padlet. There is also a very positive response with 50% using it a lot and 41,5% using it sometimes. None of the students claims that never uses the padlet.

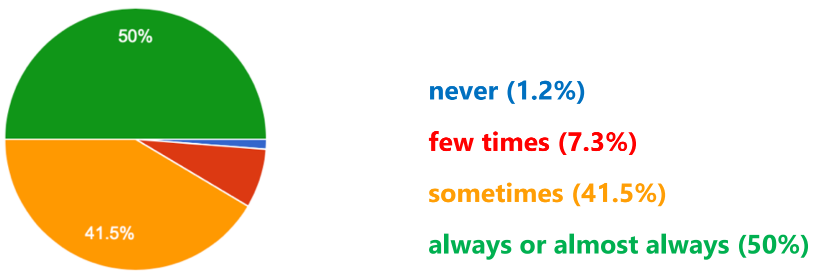

Figure 3. Use of the padlet.

5.2 Classifications

Until now, the students did 5 mini-testes (3.5/20), 2 MATLAB™ tests (2/20) and a face-to-face test (3/20). Also, 16 students already submitted theirs mini-project (4/20). From de 112 students, 99 chose to do the continuous assessment, 83 of them where already evaluated to 8.5/20 and 16 of them to 12.5/20. Figure 4 shows the results until now (in percentage) compared to the two previous academic years. It should be stressed that the previous years include also the assessment by exam (the students have two more chances of being evaluated after the CU is finished). In 2019/20 (with 120 evaluated students) more than half of the semester was online, with all the assessment online, so some of the strategies herein presented had to be used. In 2018/2019 (with 109 evaluated students) it was used a purely classical approach as previously described.

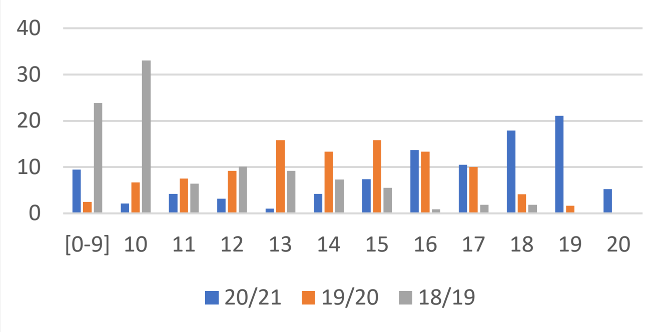

Figure 4. Grades in Numerical Methods for the last 3 academic years

5.3 Students Assessment to the CU

Figures 5 and 6 are about the number of mini-tests and MATLAB™ tests, respectively. The majority of the students is happy with the number of assessment elements. However, some of them (18,3%) thinks there should be less mini-tests and 6.1% thinks that should be less MATLAB™ tests. Only 6,1% have the opinion that there should not be mini-tests at all. None of them thinks that should there not be MATLAB™ tests, and even 3.7% thinks that they should have more of these tests.

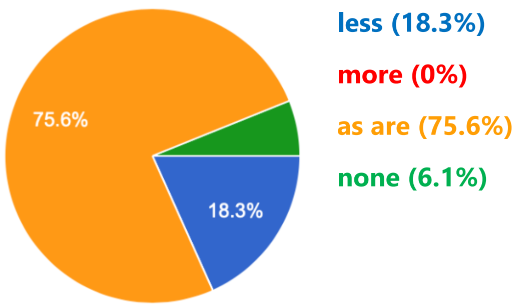

Figure 5: The mini-tests should be...

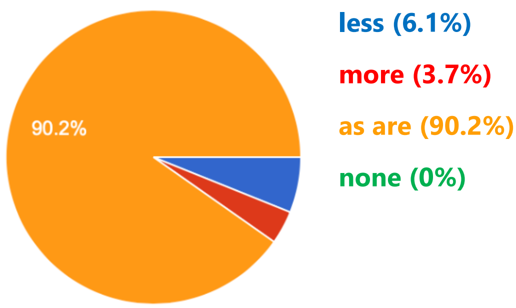

Figure 6: The MATLAB tests should be ...

The quiz also had two fields where the students could write freely positive and negative aspects about the organization of the CU. 58 students pointed positive aspects, being the most frequent the assessment method (26), the organization of the CU (22), the quality of the classes (21) and the relation teacher-student (20). Less than 10 students referred the recording of the classes, the PollEv and the use of MATLAB™. 25 students pointed negative aspects being the excessive number of mini-tests the most frequent with 12 students refiring it, which reinforces what is shown in Figure 5. It is clear that a large majority is happy with the assessment and organization of the CU, and the attendance to the classes also improved tremendously.

6 Final Remarks

The goal of transforming mathematics into a process of individual construction and a process of acculturation in relation to mathematical meanings and practices in the context of professional action in Mechanical Engineering has become a double challenge. First, because this approach requires a change of mentality both from teachers, and from the students whose behaviour, for the most part, reflects the conditioning of passive learning based on the memorization of content and the trained application of mathematical techniques for subsequent reproduction of these operations in tests and examinations. Second, because the pandemic period through which all are passing, and which demands the absolutely new practice of teleclassing, inevitably provokes doubt about the viability of these objectives under these conditions.

However, what at first glance seemed a rather significant difficulty turned into a great opportunity to implement practices, such as Flipped Classroom and Audience Response Systems, with the help of educational technological tools. The atypical conditions for carrying out the teaching and learning process cancelled the impulse of resistance to change that would probably happen under normal conditions.

Although the experiment was a success, there needs to be continuity and exploration of new ways to realize the goal of building autonomy through exploration with mutual collaboration among students to discover mathematical solutions when faced with real-world challenges.

In a non-pandemic environment, ideally, the students can use the classes to discuss the problems more freely in groups, since they don't have to maintain the social distance. The flipped classroom seemed a very useful tool to engage the students in a more autonomous work, using the time with the teacher to consolidate the acquired knowledge. Also, the mini-tests seemed a precious tool to maintain the students interested in the CU during all the semester and not only in the previous days to the final test.

7 Acknowledgments

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Integrating project management and peer assessment: a case for increased teamwork

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Abstract

In the Erasmus+ project EPIC, students from different degree programmes, degrees, universities and countries work together in groups on authentic problems for the industry. The goals of EPIC are to explore how this approach can increase students' learning and make them better prepared for both national and international labour markets. As student numbers are relatively low, EPIC allows for experiments with different ways of project organisation, such as the number of students per group and the level of integration of their contributions. Students participate in an EPIC semester, bringing different characteristics into their project team. Their level, e. g. bachelor or master and first year of more advanced, the degree programmes they are enrolled in, e. g. technical programmes, creative programmes or busines programmes, and the amount of time they invest in the project is different for each student, apart from the country of their university and their own (cultural) background. Especially with the students coming from different backgrounds and educational traditions, it is crucial to prepare them for effective and efficient groupwork during the EPIC semester. To support this, a platform called MECEPIC was developed that combines different features: exploring and outlining the background of each participating student and the added value of each student for the project, the project management and a peer assessment system that allows for reflection on the contribution of each individual student to the joint outcomes of the project. This paper aims to evaluate the use and the impact of the platform. An analysis of the data on project management and peer assessment as filled out by the students in the platform shows that it contributed to a more focused starts of the students as a team, streamlining the project and staying in control of the project deliverables and also showed that the peer assessment requires a strong involvement of supporting teachers and/or tutors.

Keywords: Active Learning; Engineering Education; Conference Information; Project Approaches.

1 Introduction

The Erasmus+ project EPIC, Improving EmPloyability through Internationalisation and Collaboration, has a number of objectives. It seeks to increase employability through closer collaboration between students and industry, by promoting active and problem-based learning, and by promoting international collaboration. The project also aims to increase the labour market relevance of education through closer collaboration between industry and academia, and make the students better prepared for both national and international labour markets in a globalized world. EPIC is focused on increasing the students learning outcome by promoting active learning methods, based on students solving real-world problems and promotes the take-up of ICT tools and Open Educational Resources (OER) to facilitate international student projects based on blended learning, thus making international collaboration more scalable and sustainable by reducing the costs. This also makes it possible to give students an international experience without the need for spending prolonged times abroad. Finally, it provides the students with transversal competencies, especially focusing on problem solving skills, collaboration skills, entrepreneurial skills and skills within creativity and innovation. Students from eight different institutions of higher education from eight European countries participate in a project semester in which they work on an existing problem from a company or institution in multidisciplinary heterogeneous teams. These teams consist of two or more students that may have different background in terms of their degree programme, their level (Bachelor or Master), the year they are in and the amount of EC they spend on the project. For the students, it is crucial to learn to work together as a team on a distance. In order to form constructive teams with a joint project plan that work together effectively and efficiently, all project semesters start with an offline project week in which the students and teachers from all participating institutions get to know each other and make a project plan. They use this plan during the remaining weeks of the semester for their teamwork and their interaction with their company and their tutor. Each project proposal is developed in collaboration between at least one of the universities and one or more companies and chosen as to fit to a theme that was established on beforehand (for EPIC, in 2020, all projects were dealing with the UN Sustainable Development goals). The project proposals are published in a catalogue, so each student can select either a topic or a specific project of his/her interest and based on this be assigned the project and group ahead of the semester. In addition to the project proposal, the company supervisor(s) would be available for co-supervision throughout the semester – in most cases virtually, but in some cases with a possibility also for a physical visit as part of the blended mobility scheme. The project setup is described in more detail by Pedersen, Kirkova, Kuladinithi and van Hattum-Janssen (2019).

The project plan that students make in the project planning week as well as getting to know each other are both essential elements in the start of a project. Powell and Weenk (2003), categorise both elements as basic student training needs. Project management is a competence not only required to complete a student project successfully, but also a competence necessary for engineers (Du & Kolmos, 2006; Ravankar, Imai, & Ravankar, 2019). The process of getting to know each other in the EPIC project goes further than meeting each other in person and finding the most adequate way of dividing tasks. As the students in the EPIC teams are different in many ways, exploring the possible contribution of each team member to the solution of the joint problem is a complicated process. The phases as distinguished by Tuckman (1965), forming, storming, norming and performing, also discussed by Powell and Weenk (2003), get an extra dimension because of the intercultural and online collaboration within the student teams. Saarikoski et al. (2015) define intercultural competences as "the ability to establish and maintain relationships, to communicate with minimal loss or distortion and to collaborate in order to accomplish something of mutual interest or need with people coming from other cultures" (Saarikoski, Lautamäki, Kaufman, & Bengoa, 2015, p. 3). They highlight the need for intercultural communication skills and the need for understanding each other to achieve common goals. The online cooperation of the student teams is another challenge that makes teamwork different. Although Çakiroğlu and Erdemir (2019) conclude that online project-based learning is possible also when all activities and project management are transferred to an online environment, even before the necessity due to COVID-19 restrictions for offline interaction, the EPIC project semesters were organised to enable an actual meetup of student teams.

In order to support the students in the EPIC student teams to effectively work together in heterogeneous intercultural teams, manage their projects and monitor the contribution of each individual student, a tool was developed to use by the teams during the project semester. The tool, called MECEPIC and based on TEAMMATES[1], combines both project management as well as peer assessment features. It consists of an online platform that is used as a team. Each team uses the platform for three distinct purposes. Firstly, they identify the characteristics of each team member, including education background, expertise and the number of ECs to dedicate to the EPIC semester. Secondly, they discuss the project and make a project outline that incorporates a clear project description, milestones and project deliverables. Furthermore, the group also defines criteria for peer assessment of the contribution of each individual team member to the team project. The MECEPIC-tool is designed to be leading throughout the whole project. By determining the personal goals, the milestones and project deliveries, and the evaluation in between and at the end, the entire project period. It is an instrument for the project members to determine the goals and milestones, as well as an assessment instrument throughout the entire project.

Peer assessment can be used as a way to evaluate the contribution of team members to a group project (Bong & Park, 2020; van Hattum-Janssen & Lourenço, 2006). As tutors nor teachers can see what is actually taking place within a team, students themselves are in charge when assessing the contribution of each individual team member to the process and outcomes of a student project team, although peer assessment can serve as a tool for teachers to provide additional support to students and be informed about who needs more attention (Ashenafi, 2017). Giving them not only the opportunity to assess each other on the contribution of each member to the project, but also making the students define the assessment criteria to do so, makes the

[1] https://teammatesv4.appspot.com/web/front/home

students not only more responsible for their own assessment process, but also makes them reflect as a team on what they value when working together and on how this can be assessed.

The peer assessment consists of three peer assessment moment that the team uses to assess all members, including a self-assessment, with regard to their contribution to the joint output. During the project planning week at the beginning of each EPIC semester, students learn to work with the platform. On day 1, they get to know each other and explore the company problem. On day 2, they identify the possible contribution of each team member and define deliverables. The third day is used to define project milestones and think about how to assess the project. On the penultimate day of the project planning week, the teams define their own peer assessment criteria, and they plan the assessment moments that they will have together with their project tutor. The last day is the presentation day and the teams share their project and assessment planning with each other. In this way, the EPIC team aimed to give the student teams a head-start with their project because of a clear planning, an agreement on what needs to be done and why in the following weeks and an instrument to monitor the contribution of each team member through peer assessment. The last EPIC edition, running in the spring semester of 2020, was the first time that project management and peer assessment were integrated in a single tool. The question is in what way the student teams used the tool for the defined purposes. The EPIC project was funded through the Erasmus+ programme of the European Union.

2 Methods

During the project planning week in the first week of the EPIC semester 2020, students needed to register themselves as a participant on the MECEPIC platform and were assigned to one of the nine student teams. In a number of sessions during this week, the teams were guided through the platform and each of the different topics. A content analysis was made of the student data to answer the following questions:

- To what extent does the platform facilitate the identification of individual contributions of team members? (part 1 and 3 of the tool)
- To what extent does the platform facilitate project management? (part 2, 4 and 5)
- To what extent does the tool facilitate peer assessment? (part 6, 7 and 8)

For each part, all responses were listed and the usability for the purpose of the platform part, the degree of detail and the meaning of the content for the student team were analysed.

3 Results

All nine student teams were asked to complete the eight parts of the tool, in order to accompany their project management and peer assessment. Part 1 was a straightforward description of their name, degree programme, year and the number of European Credits (EC) dedicated to EPIC. It was completed by all participants. Part 3 allowed for a description of the possible contribution of each team member to the project. Descriptions were given by 35 out of 58 students. Of the 22 students who did not enter any description, nine were not officially part of the EPIC project, as they came from a Brazilian university. While not funded through the EPIC project, they still contributed to the teamwork and projects on the same terms as the official EPIC students, and their efforts were recognised by their home university in Brasília, UnB. The descriptions ranged from rather general like "I will be focused on technical part of the project like frontend" to detailed descriptions like

> I can contribute with:
>
> - Costumer journey (how people will use the app, their "throwing waste out routine" linked to the routine of using the app)
> - Building the app (not in the programmer perspective, but by doing the layout, the visual structure, the requirements)
> - Validation of the app with the population
> - Data use for the SLU (how to use it in their perspective?)
> - Communication with SLU, teachers and other stakeholders

- Management of the project (time, people, things to do) *(Student response to part 3)*

The answers also showed more technical and more general aspects like project management, writing reports and making presentations. Part 2 is the first part that is aimed at project management. Student teams were asked to give a short problem definition. Eight out of nine teams completed the field for the problem description. Most of the descriptions were more aimed at describing the solution that was going to be developed, although some teams made an effort to actually describe the problem that was given to them by the company and indicate why the solution was relevant. Part 4 of the MEC platform is aimed at the project deliverables. All teams described their deliverables, also here with a large variation in the degree of detail provided by the teams, ranging from rather basic "We will create most probably a web application which runs on a server and has vulnerabilities" to detailed:

- Deliverable 1: Systematic Literature Review / Mapping: Theoretical background about the carbon footprint;
- Deliverable 2: Systematic Literature Review / Mapping: Current methods for gathering the data and calculating the emissions for carbon footprint; Deliverable 3: Systematic Literature Review / Mapping: Sustainability strategies of companies regarding emissions;
- Deliverable 4: UML model for the database, infrastructure, and apps;
- Deliverable 5: General database for storing all the activities/products and the emissions;
- Deliverable 6: Prototype Infrastructure for interacting with the database and calculate specific information (API);
- Deliverable 7: Web Interface to access and update the information. *(Student team response to part 4)*

Part 5 of the MEC tool seeks to collect the milestones of each project. As students are working on a distance and with different end dates of their contribution to the project work, this part is an important, but complicated part. One of the teams described the different end dates for the team members in this section. Other teams defined the final deadline only and nearly all teams made identified specific weeks for the deliverables. One team only defined the month is which the deliverables had to be ready. Part 6 of the MEC platform asked the students to define two sets of criteria for self and peer assessment: part 6A for three criteria on online collaboration within the team and part 6B is on international collaboration, taking into account the intercultural aspects of EPIC. The definition of the criteria included a brief description that would facilitate the assessment process. All teams defined two sets of criteria. Criteria for online collaboration include responsibility (carrying out duties, letting the team know individual progress), using scrum methodology (team members use "Trello" for regular update on tasks "In Progress", "Done", ''To Do" for every step so other team members can follow and add comments when needed), active participation in meetings (team member is well prepared for each meeting and gives relevant input on issues that are discussed where possible) and criteria related to the attitude of the team members like being and team player (communicating issues, being able to meet in the middle). Criteria for international collaboration include cultural awareness (the student is able to respond adequately to issues related to cultural differences), use of expertise (the student uses the expertise available at other EPIC partner institutions), and using English as a language. In part 7, all teams establish a schedule for the peer assessment moments based on the criteria of part 6. The platform also provided the infrastructure to carry out the peer assessment during the semester. The outcomes of the peer assessment are not discussed in this paper.

4 Discussion and conclusions

Looking at the way the students used the MEC platform both individually as well as in their teams, it becomes clear that the platform is used by each team and by nearly each individual student. As most of the parts were filled out during the project planning week, specific moments were planned for the students to work on the platform, both as a team as well as individually. Especially part 3, the individual contribution, shows a high number of missing students, which may affect the insight of teams into the available expertise negatively.

The team descriptions show a large variety of answers on all project management parts. The degree of elaboration of the problem description, the deliverables and the project milestones varies significantly between the teams. Although during the week, each team had extensive discussions internally and with teaching and other staff available, little coherence between the different teams can be found. This may be caused by the lack of explicit instruction in the platform itself. Plenary explanation to all students was given at the beginning of all sessions in which the worked on the platform, but the platform itself allowed for a wide variety of answers, from rather basic to highly detailed. For the problem description, the distinction between an analysis of the problem provided and possible solutions as proposed by the team was not clear and could have made the descriptions more focused. The deliverables had many different formats and types of content. When analysing these more in detail, it becomes clear that many of the deliverables were not actual deliverables for the company, but intermediate products for the teams themselves. Also in this case, the plenary explication during the project week was clear on the nature of the deliverables, but as the platform itself did not provide this information, not all teams took the explanation into account and described what they thought was asked for. With regard to the milestones, all teams described clear milestones, in a comparable way. If the format for the milestones would be more closed, all teams would have done this in exactly the same way.

The criteria as filled out in part 6A and 6B by all teams were quite alike. All teams had extensive team discussions on the criteria and the way they had to describe them, but in the end came to rather similar criteria that were clear indications of the way online and international collaboration in student teams can be measured. The teams all made a clear planning of the three assessment moments.

In spite of the many limitations of the platform as described, all student teams used it and aligned their project management efforts during this week. The combination of the platform and the instruction given during the week helped students to focus and to reflect on their individual and their joint efforts. Combining the individual contribution, the project management input and the peer assessment into one platform instead of organising these features in different tools helps student to experience that the way they contribute to, organise and evaluate their projects are interrelated. Students were forced to go through all steps and time was given to discuss, reflect and define all parts of the tool.

5 Limitations and future work

The MECEPIC platform is based on TEAMMATES, a sound basis for a customised peer assessment for the EPIC project but never meant for project management. The project management part is more descriptive and serves for interaction within the student teams and between the tutor and the student team. The peer assessment part of the MECEPIC platform is more in line with the original purpose of TEAMMATES. The two different parts and the use of peer assessment criteria that were defined by each student team required a highly inventive approach of the programmers who adapted TEAMMATES to the specific requirements of EPIC and improvisation skills during the project planning week. The instructions for students on the platform itself as well as the instructions during the project week may need to be more explicit to enhance the quality of their input.

The development though of a platform that supports both project management as well as peer assessment, accessible for students and tutors has proven to be useful. For the future, the authors recommend a further development of the platform to make input of the peer assessment criteria per team more user-friendly, to include more instruction in the platform itself on how to work with it, to help tutors more in their role of supervising the peer assessment process using the platform and to benefit more from the project management information during the project semester. More research on the peer assessment outcomes and their link with the online and intercultural collaboration is also recommended.

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Project-based active learning in a robotic master's degree Subject with covid combined face-to-face and online teaching requirements

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Abstract

The work proposed here tries to introduce a project-based learning methodology for the subject Sensing Systems of the master's degree in Automation and Robotics at the University of Alicante. The heterogeneous conditions of the students and the combined face-to-face and online teaching requirements made the teachers change the current teaching model based only on theoretical classes and individual practical exercises, to a more flexible schedule following a Project-based active learning scheme. One of the problems that the teachers found in this subject and the master's degree in general is the difference in knowledge between the students in the different areas that the subject cover. This is due to the heterogeneity of students who come from different degrees from various universities and even countries. Also, in this course, the teachers must deal with the situation that the incoming students graduated in the Degree in Robotics Engineering (University of Alicante) already have most of the knowledge that this and other subjects cover. This project-based learning is therefore intended to promote self-teaching to allow the most advanced students to get a deep teaching experience while the others learn the basics of the subject. The other great challenge the teachers must deal with is the adaptation to the current face-to-face and online combined teaching classes. As the proposed projects must be carried out using the robotics laboratory hardware, a carefully designed schedule for sharing the resources was made, with special attention to the current cleaning requirements. All these factors make us think that project-based learning will allow all students to acquire the appropriate skills. To evaluate the advantages and disadvantages of this proposal two surveys were carried out, one for the students and another for the current and previous teachers of the subject. The results show how this strategy got good results even for the students with no prior knowledge of the subject area.

Keywords: Project-Based Learning; Active Learning; Computer vision Education; Project Approaches.

1 Introduction

Nowadays, engineering education all over the world pays more attention to the use of student-centered teaching methods, so that students can play a more active and collaborative role in the learning process (Lima et al., 2014 & English et al.,2012). One important active learning methodology is the designated Project-Based Learning (PBL), that has been implemented in many universities across the world (Guerra, Ulseth, & Kolmos, 2017).

In order to provide the student with active learning, PBL methodology has been chosen because it is a teaching method in which teaching and learning activities are organized around a project to achieve the desired learning outcomes of the course (Sanchez-Romero, 2019). The students, as a team, work together to solve complex computer vision problems, participate in decision making, and demonstrate leadership on a variety of tasks over a period of time to achieve project-specific deliverables. PBL can be used to improve student learning, as well as to improve student participation in the teaching/learning process and achieve higher levels of involvement (Lacuesta, 2009). PBL has also made it possible to further customize the level of entry-level learning outcomes for different entry-level engineering profiles. 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.

It is not the first time that one computer vision subject is performed using a PBL methodology. Previous works (Gerónimo et al.,2013) presented a PBL scheme to form the core of the subject "Introduction to Computer Vision" of the master's program in CV and AI at the Universitat Autònoma de Barcelona (UAB). (Raval M., 2019) presented a hybrid PBL and lecture-based pedagogy where only half of the presented course was developed as a PBL scheme and the other half as the common lecture-based methodology. Another computer vision course presents a hybrid PBL and deductive based learning is presented in (Khorbotly S.,2015). This last paper presented a successful PBL approach where both students and teacher were plenty satisfied but also showed a common concern of this PBL methodologies which is that the students believe than these methodologies are a way for the teachers to avoid preparing classes.

This document describes the experience acquired when introducing a Project-Based Learning (PBL) methodology in the teaching of the *Sensing Systems* subject of the master's degree in Automation and Robotics at the University of Alicante.

This paper is organized in five sections. After this introduction, the second section presents the course conditions that the proposed methodology has to deal with. The third section presents the research methodology. The fourth section show the results of the subject course. Section five presents the conclusions of the adopted methodology.

2 Course conditions

The main objective of this proposal is to develop a new didactical methodology to overcome all the new issues that the subject *Sensing Systems* of the master's degree in Automation and Robotics at the University of Alicante has this and the next years. This subject tries to describe the vision systems, ranging from the acquisition of the image to its processing in order to obtain useful features of the scene that allow the automatic control of any system, or simply the monitoring, inspection or recognition of elements of its environment. This compulsory 6 ECTS (European Credit Transfer and Accumulation System) course is taught intensively in 12 sessions of 5 hours within three weeks. This is an important factor when it comes to understanding the operation of the subject and how an active learning methodology such as PBL will affect the acquisition of the different competences.

The summary of the new issues that this subject has this year:

- Covid-19 restrictions
  - Combined face-to-face and online classes
  - Limited physical assistance
  - Strict cleaning rules of class and hardware material
- Heterogenous students
  - Students with lower programming skills
  - Students with no prior knowledge on computer vision
  - Students with lower language level than expected

As most of education systems, the arrival of covid-19 strong restrictions has severely affected the development of the previously designed methodologies. The continuous changes in the restrictions made most of the coordinators and teachers to reorganize their educational model to try to give the best quality for their classes. Fortunately, the situation improved and allowed our university to adopt a combined face-to-face and online classes scheme for the whole 2020-21 academic year. This *dual model,* as they named, allowed a certain number of students in the classrooms and laboratories which allowed some subjects that work with hardware to cover some of their competences. In the case of the Sensing Systems subject, this allowed half of the students to be physically in class while the others being online. The other covid-19 restriction that most affected the subject was the strict cleaning rules the students and the teachers had to follow to use the class and laboratory materials which potentially reduce the usage time of the computers, robots and cameras.

On the other hand, and probably the most significant challenge, the subject had to deal with a high heterogeneity of its students. Table 1 show the different degrees that the students have. This situation is not a new one in this master's degree, but the real problem are the students coming from the Robotic engineering for the first time. Those students already completed a computer vision subject which overlap with over 80% of the contents of the *Sensing Systems*. And the previous computer vision knowledge is not the only problem as these students seem to have many other related skills that make them objectively more prepared.

Table 1. Entry profile of students enrolled in the 2020-21 academic year in the Sensing Systems subject

Degree	**Number of students**
Robotic Engineering	11
Electronic Engineering and Industrial Automation	6
Industrial Electronic Engineering	5
Mechanical Engineering	3
Industrial Engineering	2
Mechatronics Engineering	1
Total	28

3 Proposed Methodology

The proposed methodology is a project-base active learning scheme where the students try to accomplish some proposed projects with all the available resources and with the guidance of their teachers. The evaluation and organization scheme of the subject was therefore modified to give high importance to the development of the projects. The new organization system included some minimal theory classes to introduce all the topics of the subject for a total of 7 hours. The rest of the hours of the course (53h) were assigned to the project. The inclusion of that introduction theory classes was seen as necessary due to some students have never seen the computer vision concepts needed to at least understand the scope of the proposed projects. The evaluation of the subject was therefore defined as 25% coming from a final theory exam and the other 75% form the projects. That final theory exam was designed to assure at least some minimum knowledge of the subject topics.

The group of teaching members, including teachers from previous years, defined the design of the perception systems projects that were used to implement the project-based learning methodology. These projects have to cover the contents of the subject from a practical point of view and take into account the current conditions of semi-presence for their complexity and scope. An important aspect is the planning of access to the hardware elements necessary for the different projects (cameras, robots, etc.). Once the projects were defined, the documentation/guide for each of the projects was created so that, guided by the teachers, the groups of students were able to achieve the objectives of both knowledge application and self-learning in those necessary parts. The open nature of the projects allowed all kind of students to achieve a proper solution according to their levels.

Students were presented with a series of projects to choose from along with the documentation associated with each of them. The teachers guided the students to create groups of 3-4 trying to have groups as heterogeneous as possible (in terms of the grades they have). From there, it was promoted that the students were the ones designing and planning the tasks that they had to carry out. The supervision of the teachers was made with meetings with each group on a regular basis, in this way both the achievement of the objectives and the aptitude of this methodology was evaluated to provide the students with the required competencies.

4 Results

Research has been conducted on how PBL methodology affects final grades. It is important to remember that the main goal of this method is to better integrate different access profiles into the master's profile and not only the final knowledge that students achieved during the subject. Therefore, in this section, we will also show a summary of the final survey in which the students freely and anonymously described their main views on the methods used on the subject. To close this section, we added a discussion sub-section to evaluate and compare the results.

In order to measure the results of the proposed methodology we first analyse the students' achieved grades. This course the subject had a total of 28 students. A noticeable number of 5 students never started the subject, 3 of whom justified their abandon due to covid-19 reasons. Therefore, only 23 students participated in the subject. Figure 1 (left) shows the grade results of both the theory exam and the final Grade of the subject. The theory exam results showed that most of the students have at least the minimum concepts that the subject covers. As expected, the number of students who passed these minimal concepts exam is high. This is due that nearly half of this year student come from a degree with a similar subject. The theory average grade was 7.11. In figure 1 we can also see the final grade of the subject in both numerical and percentage ranges. The average of the final grades is 7.35 and over a 60% of the students got a mark over 7 and the rest got a mark above 5. Notice that 5 students, a17% of the initially signed, left or never started the subject, and they were not included in these statistics but if we included them the results would change remarkably.

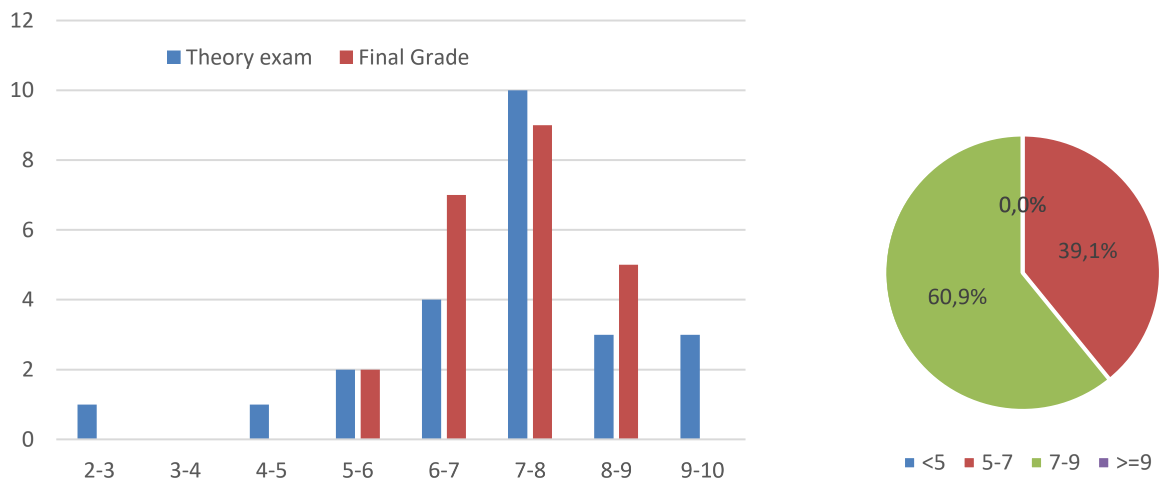

Figure 1. Left: Student grades of both theory exam (blue) and subject final grade (red). Right: Subject final grades percentages

As we stated before, two surveys were conducted to get the opinion of both the students and the teachers. Figure 2 shows the students survey results over 3 graded questions. The available answers to these questions varied from 1 (the lowest) to 5 (the highest) and they were expressed respectively with the labels *very low, low, medium, high, and very high*:

- Satisfaction degree: The level of satisfaction with the subject and therefore the proposed methodology.
- Effort level: The effort level that the students had to perform to achieve their mark.
- Knowledge/skills improvement: The perceived improvement of their knowledge and skills after the subject completion.

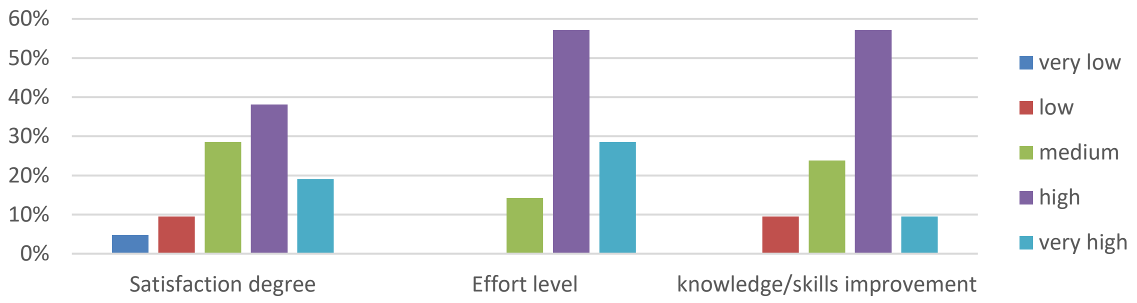

Figure 2. Student survey numerical results: satisfaction degree of the subject methodology, performed effort level and knowledge/skill improvement.

The students' results showed how they satisfaction with this methodology is above the average and nearly a 60% perceived a satisfaction above high. The effort degree got even higher percentages in the subject and 85% of students considered that this subject required a high effort.

The students' survey included an open question to include students' suggestions. One student suggested than if would have been great to have recorded classes about the whole theory content. Another one complained that his or her non previous knowledge about computer vision make him or her feel behind of his or her project peers and not being able to reach the same level in the subject time. Probably the most remarkable one was one complaining about the evaluation system of the projects because he/she was expecting a higher grade in his project due to the teachers' partial revision being positive but not having a numerical mark to regulate her/his effort to get a higher grade.

The results of the subject, which included the student grades, the completed subject projects and the student survey results, were presented to this and previous years teachers. With this information the teachers fill out the survey which included 3 graded questions with the same answer scheme than students, i.e. from 1 to 5 expressed with the labels *very low, low, medium, high, and very high*. The questions of the teachers' survey were:

- Methodology satisfaction: The level of satisfaction with the proposed methodology and the achieved results. This question in fact was the general satisfaction with the whole proposal results.
- Perceived effort: This question was not originally included in the designed survey but was added after checking the students' results. Represent the effort perceived by the teachers of the students' effort.
- Projects' scope: The level of complexity and completion of the presented projects.

Results of the teachers' survey can be seen in Figure 3. The statistics show how the satisfaction is medium-high in average. Above 50% of the teachers graded the satisfaction of the project as high or above. The perceived effort of the teachers is around medium, and the projects quality is medium-high.

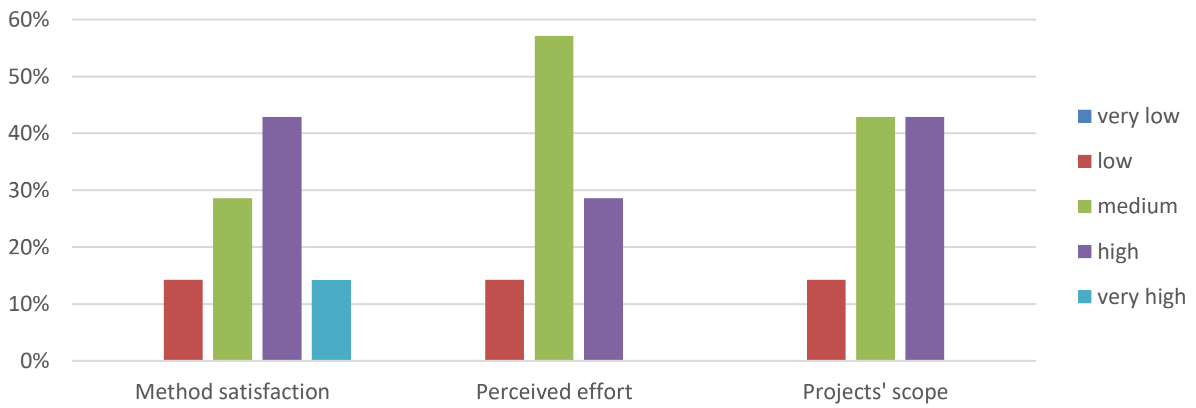

Figure 3. Teachers' survey results: Methodology satisfaction, perceived students' effort and projects' scope achieved by the students.

4.1 Results discussion

Results of both subject grades and surveys were positive but there are some topics to discuss. The final grades of the subject are like previous years and other subjects of the same master. As stated before, this year was the first with students with prior knowledge of the subject but the proposed system to increase their knowledge and skills does not seem to affect the rest of the students.

The overall satisfaction of students and teachers is positive and except some 2 complains about the methodology, this proposal seems to have overcome the new conditions that the subject presented. The only concern the teachers had was a lower perceived effort from the students work in their projects but this can be derived from the covid-19 situation and the rest of conditions that made the work in groups and with hardware material even harder.

The last remarkable result the teachers want to clarify is the good quality of the projects that some groups achieved which was way better than expected. Its noticeable how some students with real interest improved their tasks inside the project and therefore, the overall project complexity.

5 Conclusion

In general, the proposed PBL methodology was satisfactory for both the students and the teachers. The achieved results even with all the challenges that the subject had this year are promising. The covid-19 restrictions and the difference in level of incoming students did not impact in the learning experience that this proposal presented. The students qualified as good the project-based learning scheme as they could use all their already owned and new knowledge to overcome the proposed projects. On the other hand, the teachers confirmed that this BPL methodology succeed the subject situation allowing to introduce some students to the basics of computer vision while allowing the most advanced student to apply state-of-the-art methods to overcome the different proposed projects. In the next years, we will continue developing this PBL approach in this and other subject of the same master's degree where we expect the same benefits.

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The development of an Integration Methodology for project management in an adapted online environment

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Abstract

Since the closure of the dumpsite in Brasília, the waste pickers who worked there had to adapt to the new reality of receiving only at the end of the month. These changes impacted especially in the family financial management. Therefore, the Mobile Education project was created to develop a solution to assist waste pickers acquire knowledge about financial education through digital solutions. The project was planned to occur with the cooperation of four Problem Based Learning (PBL) disciplines of the Industrial Engineering course from University of Brasilia. However, the Covid-19 pandemic imposed serious changes in people's lives and also in the way the disciplines were conducted in the course. The goal of this article is to present the integration methodology developed for the Mobile Education project that occurred in an adapted online environment. This research is exploratory and has a qualitative approach. As a result, a methodology of project integration was developed to define the communication channels, the schedule management and the control of the main deliveries. This article focuses on how the management team promoted the integration among all other teams, helping them to achieve their final objective. The article's main contribution consists of discussing a way to properly manage and integrate projects in the context of social distancing.

Keywords: Problem Based Learning, Project Management, Methodology of Project Integration.

1 Introduction

In 2020, the COVID-19 Pandemic affected the entire structure of society because of the need for social distancing and suspension of presential activities, including the university ones. At University of Brasilia (UnB), the classes were also suspended and some of the projects were adapted and modelled to be occurring online. One of those projects was the Mobile Education for waste pickers, which was created by the SDG Challenge, a student-centred initiative that connects students from different universities and countries in the development of solutions and products that can be strategic to the achievement of the 2030 Agenda for Sustainable Development, set by the United Nations (UN).

The Estrutural's Dumpsite, located at Brazil's capital, was the second biggest waste deposit in the world and the biggest one in Latin America. It was closed in 2018 to minimize environmental, social and health problems. Its closure affected the income of approximately two thousand waste pickers that worked there, reducing and changing the frequency of the income received, because they were reallocated to waste cooperatives, forcing them to adapt their financial life.

Vieira, Bataglia and Sereia (2011) define financial education as measures that aim to create and transmit financial information to individuals, providing them the ability to distinguish 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, helping them to make conscious decisions that enables to save and invest, ensuring that they live well financially, whether in the present or in the future. According to Vieira, Moreira Junior and Potrich (2019), Brazil's financial education is being highlighted due to the *Estrategia 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.

At this article, it is shown how project management was used to integrate all the work fronts at the Mobile Financial Education for Waste Pickers project, in this context of COVID-19 Pandemic, remote solutions and SDG of United Nations. There were several teams working at different sides of the project courses: Production Systems Project 2, 3, 5 and 8 (PSP2, PSP3, PSP5 and PSP8). The project was divided in four main fronts: interface prototyping (PSP2), financial education content (PSP3), quality control (PSP5) and project management (PSP8). The focus of this paper is at the PSP8 team's objective: how it promoted the integration among all other teams, helping them to achieve their objectives to assist waste pickers to acquire knowledge about financial education through digital solutions.

This paper is divided into 5 sections: the first one contextualizes the theme and the research's objective; the second section shows the literature review that supports the research and provides a better understanding of it; section three reports the research methodology, explaining how the integration methodology was developed and implemented; the fourth one provides the results of the integration methodology; and the fifth section shows how the methodology can be used at future projects.

2 Literature Review

This section presents theoretical concepts that supports the research.

2.1 Project Integration

Cooper et al. (2020) defines portfolio management as a dynamic investment decision process and its final objective is to maximize the value of the portfolio list of active new projects. The new projects are evaluated, selected, and prioritized; existing projects may be accelerated, killed or de-prioritized; and resources are allocated and re-allocated. The monitoring of all these changes directly impacts the perception of final value on each activity.

According to Pollack (2016), organizational change is the most inevitable consequence of any project, and the better this change is managed, the more likely the project is to succeed, project management is also identified as an important tool that increases the chance that organizational changes be successful. The 2015 CHAOS Report has shown that lots of projects fail to achieve the expected outcome. Agile based projects resulted in more successful results and less outright failures. The report also lists factors which work together to make projects more successful. Anderson (2010) presents that the lack of clearly designated project leader, the lack of clear expectations and goals and communication challenges may lead to a project failure as well.

According to Eisner et al. (1993), integration management is the major element of systems engineering. This concept is proposed by the authors as a list of requirements, interfaces, interoperability, impacts, testing, software verification and validation, and architecture development as the main elements. Moreover, they refer to integration management, where they define the main elements as scheduling, budgeting and costing, configuration management, and documentation.

Demirkesen et al. (2017) investigates the relationship between integration management and project management performance and conclude are that several components can be used to guarantee better performance in the project. These individual components of integration management are presented as: development of project charter, knowledge integration, process integration, staff Integration, supply chain integration and the integration of changes. Understanding project management and integration were extremely important since it would provide a way to allow the project teams to achieve jointly their goal of providing financial education to people in a vulnerable reality aligned with the 2030 Agenda and its SDGs, shown in the next section.

2.2 Sustainable Development Goals - SDGs

According to the UN, the SDGs are the main focus of the 2030 Agenda, guiding the countries and their actions towards the three dimensions of sustainable development – environmental, social and economic. Their goals lead to the actions that need to be made and the measures that need to be considered to fulfil the objectives.

Their main purpose is to 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 future.

The closure of the dumpsite and built of the mobile application for waste picker's financial education is related to some of the UN's SDGs, as the target 6 of goal 11 – Sustainable Cities and Communities - which says "By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management" and 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 other status". To promote empowerment and social and economic inclusion, it is necessary to teach waste pickers on how to manage their money correctly, this topic is presented in the next section.

2.3 Financial management for low income

According to Naxin (2013), financial management is the ability to manage money and use it properly, it is also a life skill that teaches people how to survive. As presented by Wagner (2015), financial education has a positive relationship with a person's financial literacy score. The findings suggest that there are benefits to financial education, but the extent of the benefits may depend on the time horizon for changing financial behaviours. These findings will aid financial education programs. According to Anderson (2004), lower-income people tend to be less financially educated than those with higher income levels. As presented, low-income people are more likely to have limited education and are less likely to benefit from financial management training programs, that issue is due to the lack of content that low-income people can relate to during the training. The method chosen by the Mobile Education for waste pickers Project to teach financial education was through mobile learning, by the design of a gamified app prototype.

2.4 Mobile Learning

Maciel (2013) addresses the user experience of a mobile application for adult literacy in Brazil, as the author states, the era of mobility, in which we live today, allows the development of applications for education. Mobile Learning is the combination of mobile technology and education, it that allows people to learn anytime, anywhere. Maciel (2013) also states that, in Brazil, the Mobile Learning applications area is still small and has a lot of room to grow.

3 Research Methodology

The section 3 presents the method and structuring of the research.

3.1 Research Method

This research is exploratory, because, as stated in Silveira and Córdova (2009), it views to provide greater familiarity with the problem, in order to build a justificative. Also, it has a qualitative approach because, according to Gerhardt & Silveira (2009), it doesn't quantify the value and the data analysed is non-metric. The study object of the research is based on how the integration of the Mobile Education teams occurred in order to assure the success of the project in an adapted online environment. The inputs needed for the integration methodology development, described in section 3.2.1, were collected by informal alignment meetings with the four main stakeholders: representatives of PSP2, PSP3, PSP5, PSP8 and the Mobile Education project general coordinator. After understanding the demands, the integration team did a brainstorming session in order to discuss how to build the monitoring framework, what were the best tools to use, and how to provide communication between teams.

3.2 Structuring of the Research

The study is structured in 4 phases: (1) Contextualization of the project, (2) Development of the integration methodology, (3) Monitoring the implementation of the methodology and (4) Project results.

3.2.1 Phase 1: Contextualization of the project

Since the project was composed of different teams, it was necessary to properly understand the demands and deliverables of each one. To do that, the first step was to identify all the actors involved and getting in contact with them. After that, the alignment meetings with the project teams and the main stakeholders were arranged. The meetings allowed the alignment of the expectations of the stakeholders and the identification of the deliverables for each team, giving the integration team a better understating of the project as a whole. Then, to formalize what was decided, the integration of the project teams was mapped. The tool used for the mapping process was Miro, an online collaborative whiteboarding platform that enables the drawing of different flowcharts.

3.2.2 Phase 2: Development of the integration methodology

After the contextualization of the project was completed, it started the development of the integration methodology to ensure that each project team was going to receive everything needed and provide the input for the other teams. First, was analysed what was necessary for the integration to be effective. Some of the questions answered in this step were: How often do the teams need to communicate? How much a team needs to be aware of the other team's deliveries? What is the best way for this communication to happen?

After that, it was analysed the available technologies to choose with one would provide a better space for this integration to occur. To make this choice, it was important to consider that the project was inserted in a university environment and was done in a remote structure, due to COVID-19 restrictions. When the technology was chosen, it was done a brainstorming section - between the integration team - to decide how to build the monitoring framework. This framework was important because it would be the best way to assure that each team was going to stick with the schedule and also it was a way to provide a holistic view of the development of the project teams.

The project schedule was defined through the alignment of the delivery dates of each project team. The project leaders shared their specific schedules and decided together when they would need to deliver their contribution. All the schedule was transferred to the platform Microsoft Planner and it was managed using the same tool by the integration team. When everything was defined it was important to formalize what was decided and how exactly the integration methodology would work. To make the methodology more visual for the project team members was done a presentation using Microsoft PowerPoint as a tool.

3.2.3 Phase 3: Monitoring the implementation of the methodology

Once the integration methodology was elaborated, the next step was to ensure that all team members were aware of it. To do that, it was arranged an alignment meeting with the team members and some of the stakeholders to present the methodology created. The meeting was done on an online platform and recorded so that the ones who couldn't make it could have access to it. Also, during the development of the project, the integration team supported the teams that had any kind of problem when using the methodology proposed.

3.2.4 Phase 4: Project results

After the end of the semester, the results of the project were analysed and, especially, how the integration methodology contributed to it. To understand how the team members felt about the use of the integration methodology, there were made informal meetings with some of the team leaders. Their impressions and suggestions for improvement in the methodology are made in section 4.4.

The section 4 shows the result of the research.

4 Results

Section 4 presents the results obtained from the methodology of project integration. As presented in Section 2, a literature search was made in order to understand what tools and frameworks were already used on similar projects, however, no results presented solutions to the project needs.

4.1 Contextualization of the project

The goal of the Mobile Education project was to design and develop a platform that would teach waste pickers financial education. Since there were many work fronts in the project, the first step was to identify the actors and stakeholders involved to identify the deliverables for each team. As a result of these interviews, the main integrations were mapped and are displayed in Figure 1.

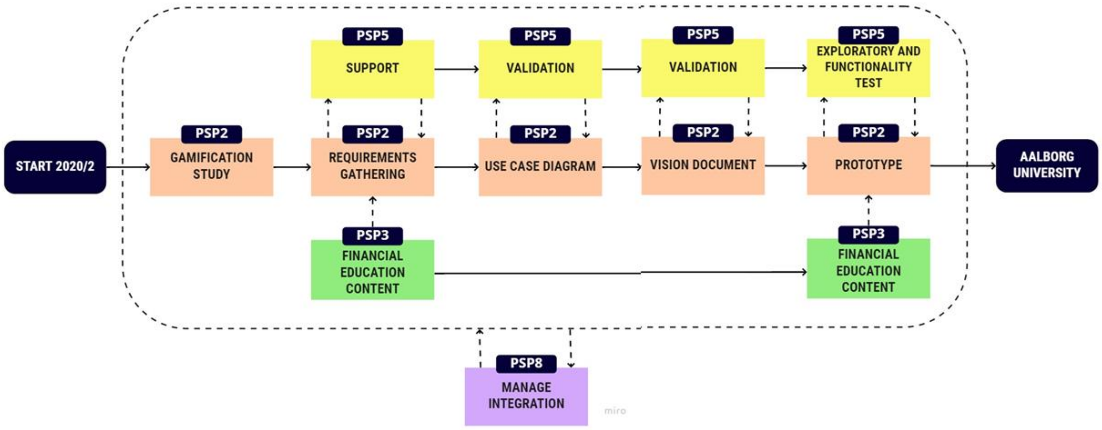

Figure 1. Overview of Project Integrations

The project had around 35 participants, including Brazilian and Danish students. At UnB, the students were divided into project teams that were responsible for different parts of the development of the prototype. Those project teams were: PSP2, PSP3, PSP5, and PSP8 responsible, respectively, for the interface prototyping, financial education content, quality control and integration of the teams. Also, there was a computing team of students from the University of Aalborg (AAU), Denmark, responsible for the back-end coding of the solution, which would be done after the Brazilian teams finished the prototype. Each area had a professor responsible and there were also stakeholders representing the SDG Challenge initiative and the Central Bank of Brazil.

4.2 Development of the Methodology of Project Integration

Since it was not possible to organize presential meetings to promote the integration, the choice of the channel of communication turned out to be one of the most important steps in whole the process. The key factor in this choice was to look for tools that are financially accessible for the stakeholders and the ones that the usability allows the design of a framework compatible with the project management methodology selected. As the educational activities in UnB were adapted to these atypical circumstances, a partnership with Microsoft made Microsoft 365 available to all the students. Since the students had free access to Microsoft Teams and Microsoft Planner, those tools were presented to be the most compatible with the integration development.

In addition to Teams and Planner, it was important to create another channel to promote easier and more agile information exchange. Again, availability played a key role in the choice, and WhatsApp was defined as one of the communication channels since it is a common messaging app in Brazil. The team leaders were united in one group in the app to share important warnings and to exchange information. To keep track of all the interactions between teams, an Excel sheet was built inside the Microsoft Teams channel. The sheet was used to schedule the meetings needed and to register the meeting progress. Every team had its sheet to register important data like date, main subjects, participants, discussed topics, and pendencies.

As the tools and the limitations were considered, the integration team agreed to adapt the methodologies proposed by Beck, Kent, et al. (2001) and Sutherland, Jeff, and J. J. Sutherland. (2014) to build the online framework. Once the tools and the framework were set, it was important to understand how the integration methodology was held together. In Figure 2, an overview of the methodology of project integration is provided.

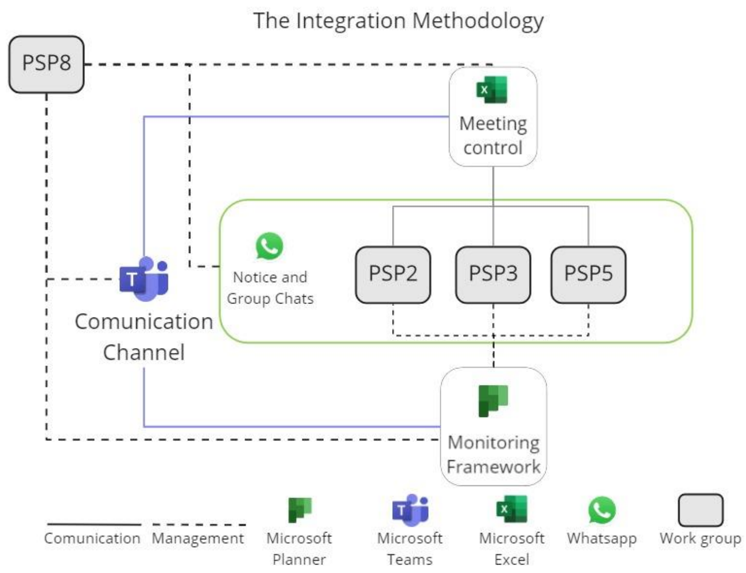

Figure 2. The Integration Methodology to The Mobile Education Projects

Figure 2 helps understanding how the tools connect and built the system to make sure all the information is easily accessed and displayed in a way that each member of any team can understand the current situation of the progress of all teams individually and collectively.

4.3 Monitoring the implementation of the methodology

When it comes to the development of an agile methodology, it is important to revaluate what can the team change on management routine in order to become more effective, adjusting the behaviour regularly as said Beck, Kent, et al. (2001). Having it said, it was important to be prepared to adapt to any circumstances that could appear during the project development. The whole integration methodology was sustained in the progress shared in the framework designed, and the chart itself was built on a backlog basis. During the first iteration of the framework, the integration team noticed that some teams were having trouble adapting their internal task management to the sprint planning required in the framework, once they were using the PMBOK management methodology instead of the agile system proposed based on widely used, and written by many authors, SCRUM board, which classify the tasks as "to do, doing and done". This issue was easily solved once they translated some tasks of their analytics project structure into backlog tasks. This translation was successfully achieved by understanding which products of their analytics project structure would be used as inputs to another team's backlog task, translating them into their backlog tasks. As shown in the latest version of the framework displayed in Figure 3.

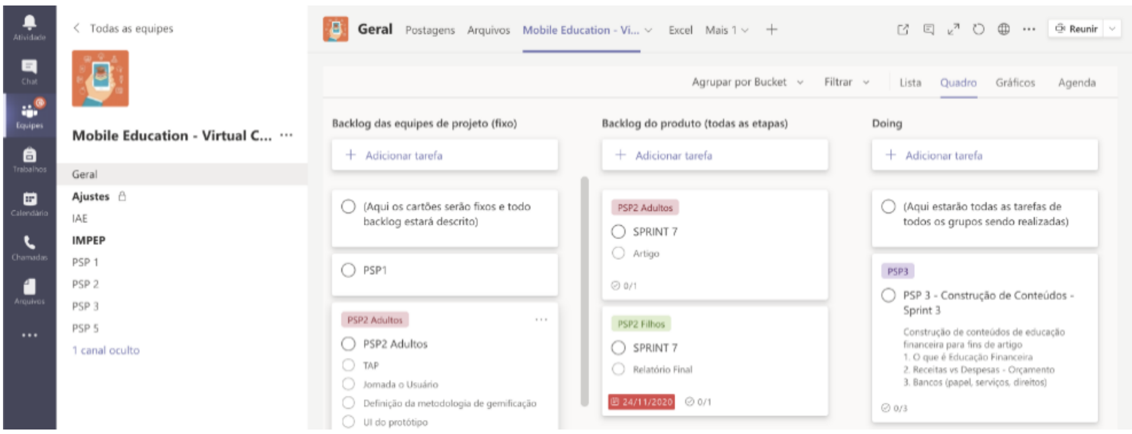

Figure 3. Integration Management Framework

The framework was organized into four buckets. The first one was fixed and used as a guide for the fastest visualization of the whole backlog of every team. Each task stood for a team and each subtask stood for a backlog task. The other three buckets stood for backlog – tasks to be done, doing, and done. Every subtask listed on the first bucket was copied to the second one and then moved to the following as it was completed. To make sure it was easy to find your tasks, there were filters to help to find the tasks of specific teams.

Once listed as a benefit of the WhatsApp group tool, the facility of information exchange on the WhatsApp group ended up overshadowing other tools that also had an impact on the project's success. This issue impacted by making some developers use the app to share documents and make meetings appointments, losing track of the information required by the Excel sheets, and failing to share their progress properly on the chart. This problem was solved by talking individually to the team leaders to make them set the integration methodology orientation as their team routine.

4.4 Project results

As predicted at the beginning of the integration design, the social distancing had a huge impact on the communication between the developers, especially when it comes to a framework based on the agile methodology. The impossibility of making SCRUM daily meetings proposed by Sutherland, Jeff, and J. J. Sutherland. (2014) challenged the integration management team. It was also difficult to teach every team how to use the framework proposed without a presential meeting to present them the methodology.

Despite these setbacks, the integration management team was able to overcome these difficulties, guiding a large number of developers into achieving impressive results with the integration methodology presented. The Mobile Education for Waste Pickers Project also managed to propose a product that can generate huge impacts on the waste pickers' life while dealing with the challenges presented by the pandemic. The main result of the Project was to design a gamified app prototype that aims to improve the financial literacy of these waste pickers and their families. The app also helps to achieve the SDG goals by providing financial citizenship to a vulnerable class. Figure 4 presents the first version of the prototype, jointly developed by the project teams in a PBL environment.

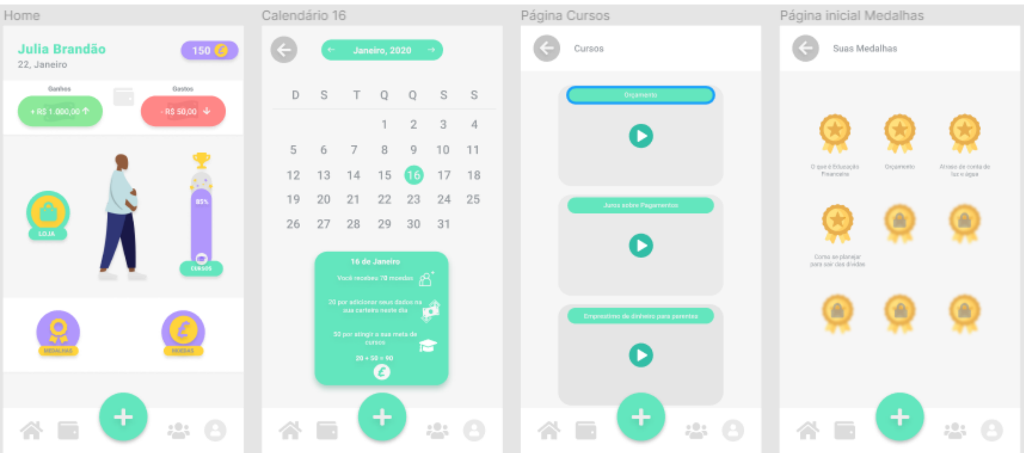

Figure 4. The Mobile Education app prototype.

Regarding the methodology of project integration, every tool selected plays an important part in the integration system. Table 1 specify how every integration need solution was designed and which challenge comes along in the adjustment of the tool to the management framework.

The framework proposed with the selected tools allowed multiple teams to work together despite the challenging situation imposed by the pandemic without missing any task listed in the backlog. Once the project came to an end, the team in charge of the integration management was invited to present their results in a quality webinar event at the UnB.

The framework proposed with the selected tools allowed multiple teams to work together despite the challenging situation imposed by the pandemic without missing any task listed in the backlog. The integration methodology was adjusted during the semester and validated by the students and the professors involved by revaluating, adapting and talking regularly with all the developers involved in the project, as suggested by

Beck, Kent, et al. (2001) and Sutherland, Jeff, and J. J. Sutherland. (2014). Once the project came to an end, the team in charge of the integration management was invited to present their results in a quality webinar event at the UnB.

Table 1. Benefits and challenges of the proposed methodology of project integration.

Integration need	Tool	Benefits	Challenges
Monitoring framework	Microsoft Planner	- Keeps the progress visible to every member; easily accessed.	- How to neatly display the teams backlogs separately; - Exemplify the usage of the tool's features.
Communication channel	Microsoft Teams	- Gather information in one place; - Easy access to video meetings; - Everything is registered in the platform.	- Include all the project members in the tool.
Meeting control	Microsoft Excel	- Easily display the main topics discussed.	- Engage the groups to fill in the tool after the meetings.
Notice and chat groups	WhatsApp	- Frequently accessed by the users; - Fast and fluid communication.	- Include all the project members in the tool.

5 Conclusion

The Covid-19 Pandemic has imposed serious changes in people's lives and institution's functioning. Industrial Engineering's Mobile Education for Waste Pickers project needed to be adapted, so as the teams working at it. For that reason, it was important to have a team responsible for managing the integration among the various fronts of the project.

Because of that, a methodology was developed on how to build the monitoring framework and what it needed. After its creation, alignment meetings over the integration methodology were made with the project members to teach them how to register and keep the other teams informed of their progress. By using the methodology, it was possible to develop a first version of the app interface for waste pickers' financial education, gathering the products of all the teams. This solution achieved provides help to achieve the 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 other status".

In this multifaced project, where there were various groups, tasks, and deliveries involved, some teams' deliveries were needed to the progress of the other parts. In this case of interrelated activities, the schedule management was noticeable and necessary to assure that each team was going to stick with the schedule, providing a whole view of the project to all involved in order not to generate delays. Due to the end of the semester, it was not possible to collect feedback from the managed teams and students about the effectiveness of the methodology of project integration implemented.

In future works of online integration among teams, it is recommended that all the parts of the project know the importance of the integration and management to ensure that all information and progress is registered and known by all the parts working, guarantying the best communication and deliveries among the teams, because existing communication channels, as WhatsApp, may overshadow the methodology of project integration created. Also, it is important to absorb the feedback from the affected by the project management about its efficiency and performance, to improve later works.

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Using PBL to design a gamified application prototype: the case of waste picker's children financial education

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Abstract

The dumpsite of Brasilia, Brazil, was shut down in 2018, and since then the waste pickers had to adapt their lives to a new reality. Before then, they used to earn money working autonomously by picking valuable waste amidst the waste mountain. But now, they were reallocated in modern recycling cooperatives, and thus receive incomes regularly and at the end of the month, with a significant impact in their family's financial management. This new labour organization demands new ways or managing finances, with the support of software applications that brings financial education to waste pickers and, in this case, to their children. This paper describes the process of designing an application in this context. It took place through the union of various courses that use the Problem Based Learning (PBL) methodology, at the Production Engineering course of the University of Brasília. We present here the results of students of Production Systems Project 2 (PSP 2) team, whose objective was to plan, specify, validate, and prototype the interface of a gamified financial education application for children of waste pickers. A literature review about interface development, mobile learning and gamification was conducted, then a user's journey was defined, and user´s interaction and the scoring system was set. Software requirements were defined in a vision document use case diagrams and the application's interface was prototyped. Thus, this article discusses what would be the best way to use game techniques to boost financial learning in the context of the children of waste collectors.

Keywords: Mobile Learning, Gamification, Financial Education, Interface Development.

1 Introduction

In 2018, the largest dumpsite in Latin America was closed (SLU, 2018), as stated in the annual report of activities of the Brasilia Urban Cleaning Service. Thus, the entire waste collection system of Brasilia (Brazil) and the lives of those involved in this process have undergone drastic changes. The waste picker's families who make their living from the dumpsite had to adapt to a new reality. In this context, the University of Brasilia identified the opportunity of offering financial education to those families. Financial education in Brazil is neither present in the family universe nor educational institutions such as secondary schools (D'Aquino, 2007), and this is also a necessity for waste pickers children. Thus, we proposed to develop a prototype of an application that would foster financial education to these youngsters. There are several ways to promote education, but, in this case, create an approach that could motivate the waste picker's children, via a gamified approach was the goal of this paper. The use of gamification for education purposes has increased (Lee and Doh, 2012) and our methodology consists of using game elements out of context, to motivate individuals to action, thus helping them to solve problems, and promoting learning (Kapp, 2012).

Four teams from 4 different Production Engineering PSPs coursers (i.e., Production Systems Projects) of the University of Brasilia (UnB) were the main collaborators to made up designed the prototype of the project. The courses apply Problem Based Learning (PBL), and each team is responsible for a part of the solution. The PSP 3 team developed the content that would be in the app, PSP 2 designed the interface, PSP 5 did the quality control of the prototype developed by PSP 2, and the PSP 8 team managed the integration of the project. These courses, provided by the Dept of Production Engineering of the University of Brasília, have as main goals to: apply PBL in a transversal and integrated form.

The four teams interacted through a PBL methodology, then the teams were capable to jointly find a solution to bring financial education to the children of the garbage collectors. Throughout the project, the teams discussed the main aspects of the problem and formulated hypotheses for solving the problem together with the stakeholders. Also, the development of soft and hard skills by the students who participated in the project was a relevant outcome of the use of PBL. Thinking, decision-making, adaptability, teamwork, and stress management were the main soft skills developed during the build-up of this paper.

This paper focuses on the results of the PSP2 team is presented in 5 topics: i) the literature review which provides a better technical basis for the development of a solution; ii) the methodology used in the research for the creation of a product that combines a mobile application, financial education, and gamification; iv) results and v) conclusions.

2 Literature Review

A literature review was conducted to show an overview of the subject matters and methods within each existing field, to understand the state of the art and how it could relate to the objective of this work.

2.1 Financial Education

Lührmann et al (2015) point out that the low level of financial education of adults is correlated with bad financial aspects, such as fewer savings and less wealth. The authors evaluated the effect of financial education on adolescents, and this study revealed that it significantly increases their interest and self-rated financial knowledge. According to Lührmann et al (2015), this is a major result because increasing the interest of adolescents is the first step in increasing engagement with financial issues in the future. Soares & Costa (2012) present a financial education game developed to be used as a tool for teaching financial concepts for children of employees of a Steel Mill in Brazil. They pointed out that many authors sought to correlate the Level of Financial Education with possible future impacts on consumer behaviour.

2.2 Gamification

According to Nakashima (2017), the use of scoring and ranking approaches helps in teaching by leaving users enthusiastic and motivated in learning, and as it progresses, increases the competitiveness of users. The application developed by Nakashima was based on gamification to perform a behavioural change in users. Zakaria (2020) also corroborates the view of behavioural change provided by gamification, by exposing the benefits of a different learning methodology, which can make learning more enjoyable to the user. These authors believe that the use of the application enables creative and intuitive skills which encourage students to learn a theme attractively and effectively.

2.3 Mobile Learning and User Experience

Maciel (2013) addresses the user experience of a mobile app for adult literacy in Brazil. The author states that the era of mobility in which we live today allows the development of applications for education. By combining mobile technology and education, a new category called Mobile Learning was proposed which allows people to learn anytime and anywhere. This approach seemed interesting because it is a natural evolution of technology. In Brazil, the mobile learning application area still growing, and the study conducted by Maciel (2013) revealed some interesting considerations: (1) it is important to provide training for family and friends who support the user and (2) the voice guide of the app has positive impacts because it makes interfaces more humanized. When it comes to user experience, Lu (2011) also points out that users want to discover things instead of reading instructions or relying on memory, meaning that they want to interact with the system easily and fluidly.

3 Project Methodology

The application was projected by using gamification to meet the target audience to engage and motivate users of the platform, based on Zichermann (2011). Therefore, by using elements of games, such as the use of strategies, thoughts, and varied mechanics outside the context of games, one provides motivation, helps users solve future problems, and promotes learning, according to Kapp (2012).

3.1 Research Method

The User Interaction Plan of the application was built to promote competitiveness and a sense of belonging to the community of the users (to promote competitiveness and join the user into the network of users of the app), by using these tools: ranking and private chat. The Scoring System, a vital part of gamification, was designed based on the elements described by Klock et al. (2014), which suggests the increase of motivation and engagement of the app's users, such as levels, scores, achievements, and ranking. Klock et al. (2014) also argue that when working with a scoring system and levels of experience, the user is encouraged to meet their goals and make achievements in the application, thus seeking to complete the activities proposed in modules of the application.

In addition, a literature review was performed via a bibliometric search on the Web of Science platform, to better understand the state of art. The search was based on the subject of apps that use gamification, and the following keywords were used: "App" AND "Gamification", and for the topic of Financial Education the terms "financial education" AND "teenager*" were used. These terms were chosen to help understand how personal finance education is generally approached and also to understand what the results of gamification-based teaching apps are. The bibliographic search was based on scientific papers published from 2010 till 2020.

Gamification was the first phase of the project. It aimed to explain and document the initial concept of the application, in a specific and subdivided way. Thus, three artifacts were developed: the User Journey, the User Interaction Plan, and the Application Scoring System. As evaluation criteria, all was evaluated and approved by the initiative's stakeholders, especially the PSP 5 team, that was responsible for the quality control.

The User Journey is a general mapping of the processes carried out in the app, from the first access until the end of the game, which has the adolescent target of the project as an actor. We used the Business Process Model and Notation (BPMN) methodology in an online software for diagram creation so that the team members could work simultaneously.

The User Interaction Plan had the purpose of establishing different ways of interaction among those who use the platform, thus ensuring reciprocal influence, greater engagement, a sense of belonging to the application community, and promoting competitiveness. Many proposals were raised based on existing systems that already meet this objective, so two strategies were selected: ranking and private chat.

The elements described by Klock et al (2014) were used for the Scoring System, a vital part of gamification. They argue that when working with a scoring system and experience levels, the user is encouraged to meet their goals and accomplish achievements in the application, thus seeking to complete the activities proposed in modules of the application. The scoring system was elaborated to foster motivation and a way to monitor how users progress and learn the themes. It also followed common strategies and characteristics of games, such as the attribution of points, rewards, and classification by several points. The structure was based on six topics: Levels, Module Scoring, Extra Points, Store, Ranking, and Achievement Gallery.

To plan the app, a vision document was written 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 use case diagrams), constraints, and a primary interface prototype.

The vision document was essential to present to the stakeholders (teachers and other students) the steps taken so far, to elicit the functional and non-functional requirements via 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. All these outcomes are presented in the Project´s Results section of this paper.

The prototype was implemented based on the outputs of the Gamification phase and the vision document, thus representing the proposal visually and meeting the experimentation phase of the solution. The Canva® platform was used to create the application designs, and the Marvel App platform was used to create the interactive mock-up. Furthermore, the prototype was inspired by applications that present analogous educational requirements, such as Duolingo and Trivia Crack, and games like Two Dots.

4 Project Results

The application's functionality objectives were aligned with the literature review, the mapping of the processes present in the prototype, the interaction plan between users, the scoring system, and finally, the model's interfaces were developed. The PSP5 team was responsible for validating every product used for the development of the prototype, along with a teacher they used PBL to analyse if the requirements defined for development were in fact what the stakeholders needed and they checked the quality of the products.

4.1 User Journey

Figures 1 and 2 represent the User Journey's diagram, which was divided in two parts for easier visualization.

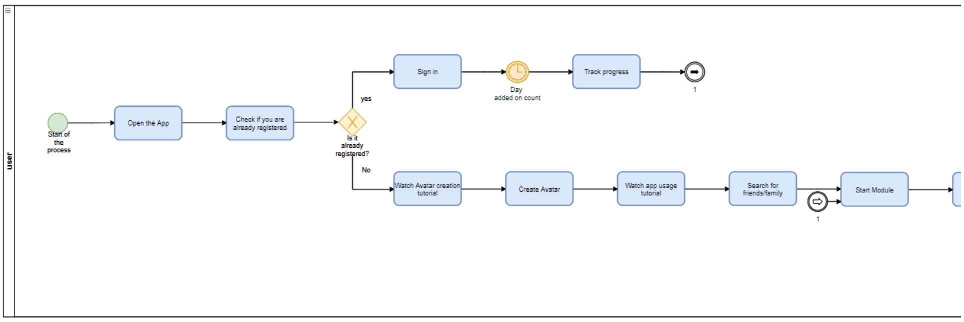

Figure 1. Part 1 of the User Journey.

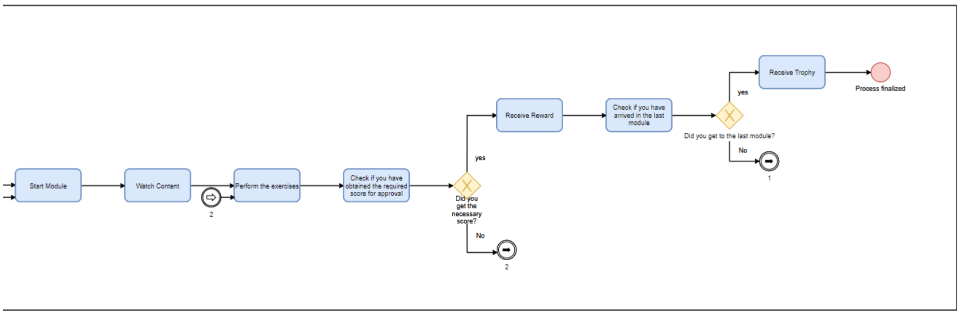

Figure 2. Part 2 of the User Journey.

First, the user must login or register via a profile creation tutorial, via an avatar. Then the user must watch the tutorial on how to use the app, and once he has completed all the steps, the user can start to use the app, thus beginning with the modules of activities proposed. If the user is already registered in the system, he/she will have to login to enter the teaching environment of the app. The user can track his/her progress from the point where he/she stopped and thus begin to perform the modules, represented in the diagram by the link. It is important to note that for each login made with a difference of twenty-four hours, 1 day will be counted in the user's progress, thus being able to display this sequence of days in his profile, receiving a reward for consecutive use.

The next step the user will take after the login step is completed is watching the audio-visual educational content. After that, the user will do exercises on the presented topic, with 10 exercises per module, where a right answer equals one point and a wrong answer equals zero points. The user must obtain a score equal to or greater than seven points to finish the module´s tasks. At this point, the diagram shows the second exclusivity gateway, represented by the question, "Did the user get the required score?" If the answer is "no", the user must restart the module and attempt to obtain the required score, represented in the diagram by link 2. If the answer is "yes", the user will receive a reward.

After completing the module on the specific topic, the user will go through the other modules proposed by the app until reaching the last module. The last exclusive gateway of the diagram is shown at this point, where it presents the question: "Have you reached the last module?" If the answer is negative, the user will go back to link 1 (already shown) and must start the module again. If the answer is affirmative, the user will receive a trophy, informing that he/she has successfully completed the modules on the proposed subject, thus ending the process and looping at each module of financial education subjects.

4.2 User interaction plan

The user interaction plan is composed by the ranking system and the private chat. The ranking system makes it possible to classify users, based on their scores so that each user has access to the names of the top ranked users. This alternative has the objective of generating greater adherence and commitment to competition game in the app.

Private chat is a feature used in many mobile apps. Its implementation aims to generate a multifunctional app, by enabling more than one alternative of use for the user. In addition, the private chat will provide direct interaction between users, so that they can exchange information and help each other in the quiz exercises.

4.3 Scoring System

A scoring system was developed to offer points for each day the app is used, to win prizes and medals, to observe the position in the ranking, to level up according to the accumulation of XP points, and to customize the avatar by exchanging the cans (a score symbol, based on soda cans) obtained for products offered in the store. The system was developed to create competitiveness and motivate the use of the app continuously.

The user must create his/her avatar when registering and logging into the game for the first time, and this avatar will represent them in the app. All avatars start at level 1, with the possibility of reaching level 100, and the user must earn a certain number of Experience Points (XP) to advance to the next level.

The module scoring system will be used to establish the ranking between the users of the application, and each module will have a certain number of exercises so that users may earn cans and XP as they complete them. The metal cans represent points and the user will receive 7, 5 or 3 cans when he/she completes the exercise on the first, second or further attempts, respectively. They user will earn 50 XP regardless of how many attempts he/she needs to complete the exercise. They will earn 5 Cans and 200 XP after completing the module´s task, as well as a medal for each module. These medals will be displayed in the user´s Achievement Gallery.

An online store where the points earned (represented by cans) may be used will be available. Users have the possibility to exchange the cans that they obtained to customize their avatar. The items will be unlocked for purchase as the user levels up. The system is weekly updated and creates a Ranking by using the amount of XP users obtained. The first, second and third place in the weekly ranking will receive 40, 30 and 20 cans, respectively, as a bonus. The Achievements Gallery is where the user can check all the awards received in the app and what other achievements they can still pursue. This gallery shows the medals gained at each module and the special medals from both the Temporary Challenges and the Daily Sequence.

4.4 Requirements listing

Initially, a high-level requirements list was created in the solution preparation phase within the vision document to specify the needs requested, and then to develop the use case diagram and to create the prototype interfaces.

The project requirements were divided into 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 and the requirements in both tables were validated by the stakeholders.

Table 1. List of the application´s functional requirements.

Nº	Name	Functional Requirement´s Description
RF001	Register and log in	It allows performing user registration by storing information, user and password, or linking to the user's social networks.

RF002	Diversify Modules	It allows diversifying the modules related to pre-defined financial education topics - What is Financial Education, Revenue vs. Expenses (fixed, variable, casual), Banks and Retirement Planning.
RF003	Level modules	It allows offering different levels of difficulties taking into account the specificity of each module. It presents educational content.
RF004	List modules	It allows listing the modules learned by the user to indicate the progress.
RF005	Manage search	It allows searching for a user to be able to add them as a friend.
RF006	Show score	It allows displaying general and friends ranking.
RF007	Create Profile	It allows creating a custom avatar.
RF008	Edit Profile	It allows changing avatar characteristics.
RF009	Manage profiles	It allows managing the registration of categories by administrators.
RF010	Manage modules	It allows managing the registration of modules by administrators.
RF011	Guide user	It allows offering spoken instructions to improve user´s understanding, especially for those who cannot read.
RF012	Orient user	It allows to present feedback to the user's actions, with messages that encourage the user to make the correct answers, but that does not discourage him/her when reporting errors.
RF013	Consecutive days of use	It allows to present the user the number of consecutive days of use of the application.
RF014	Purchase products for customizing Avatar	It allows displaying a virtual shop that enables exchanging points conquered by the user for artifacts for the avatar.
RF015	Perform knowledge test	It allows applying a knowledge test at the end of each module, based on the contents taught in that specific module.
RF016	Show private chat	It allows viewing the private chat between two users.

Table 2. Non-functional requirements listing.

Nº	Name	Description
RNF001	Accessibility	The user interface must be easy to learn, use and understandable for the illiterate.
RNF002	Responsiveness	The system must be navigable by cell phone and other devices
RNF003	Off-line usability	The application must work offline.
RNF004	Synchrony	The application must remain in sync whenever connected to the internet.
RNF005	Transparency	Data synchronization between server and application must be transparent to the user.
RNF006	Size	The application must not occupy more than 50 MB of cell phone storage.
RNF007	Performance	The application must not overload the cell phone system.
RNF008	Multimedia utility	The application must be able to present audio-visual content (image and sound).
RNF009	Reliability	The application must record the users progress made.

The use case diagram shown in Figure 3, was designed out the functional requirements list, and the understanding of the business model.

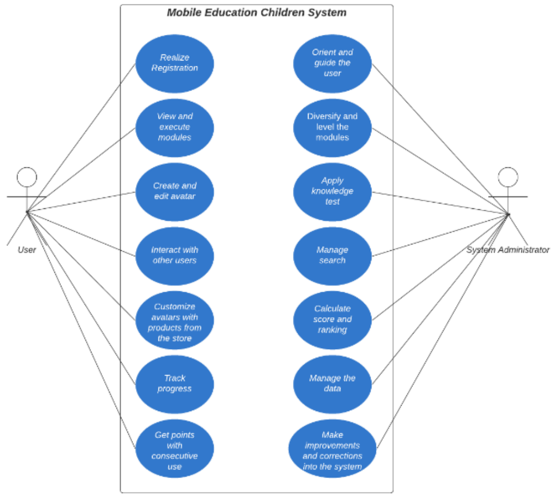

Figure 3. Use-case diagram.

The use-case diagram represents the interaction between the user and the system administrator, and their main assignments within the application.

4.5 Prototype Interfaces

The application interfaces were designed, according to the particular needs of the main users of the system, and based on the functional requirements and the use case diagram. Some special options were conceived, considering that the user could be illiterate or functionally illiterate. Therefore, the system offers solutions that allow this user to understand the information exposed by the system, the options to listen to the texts present on the screen and choose the correct alternative among the colors presented in the options of the answers to the quiz.

The system offers the creation of avatars, communicating from chats, locating users, the option of logging in via social networks and find mutual friends who use the app as well, in order, to bring users closer together and to boost the use of the application through virtual human interaction.

The functionalities can be seen in Figure 4, which show the interfaces designed for the prototype.

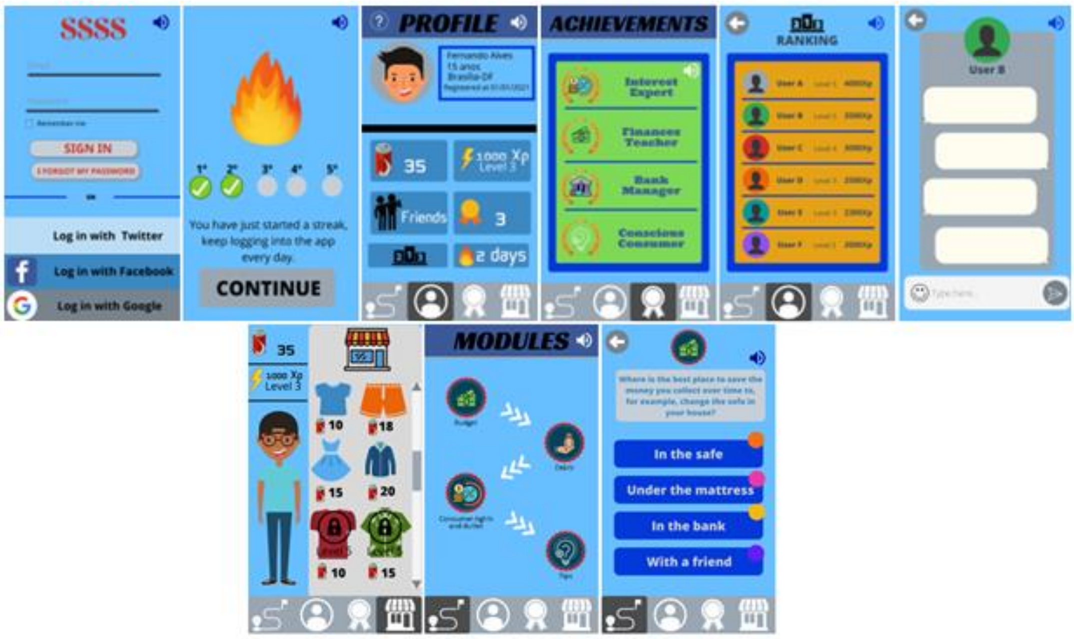

Figure 4. App interfaces (1-9) developed using PBL.

The interfaces 1 to 3 shown in Figure 4, represent, respectively, the login screens, the daily access control system, and the general profile, which shows the user's personal information and those related to the progress in the application gamification system. It is also possible to access the achievements, the ranking, and the chat, by clicking on the medal and podium symbols, and on the "Friends" button, respectively, by the profile screen.

In the interfaces 6 to 9 from Figure 4, the screens demonstrate that in addition to the features described above, the application also allows the user to create his avatar, track the progress, listen to the questions and its answers options, as well as mark the correct one, by using the colors that are associated with each alternative.

5 Conclusions

After the change in the way waste pickers work, it is remarkable the importance of providing financial education to them and their families, so that they can adapt to their new way of working, organize financially and not to have problems with financial institutions. For this purpose, a prototype of a mobile app was created in order to provide financial education to the children of the waste pickers through a gamified interface, as a result of this project.

Besides the main project objective, this work also had the purpose of developing students through problem-based learning (PBL). This goal was also achieved through the integration between the classes of Production System Project of the Production Engineering course of the UnB of students from different semesters, as well as the contact with the waste pickers and the immersion in their reality, which enabled a greater autonomy of the students in the resolution of conflicts during group work and a greater deepening of the concepts taught in the classroom.

The PBL methodology was used during the project to promote several skills, among them an effective communication between the disciplines and in the tutorials provided by the teachers and students, generating an effective problem solving and resulting in several lessons learned. The technical learning in the elaboration of the BPMN mapping and the capacity for collaboration and organization are highlights, as well as the evaluation of the students of the PSP5 discipline, which was essential when validating the quality of the project as a whole through formal technical instruments for improvement. For the elaboration it was necessary a process of individual self-learning among the participants despite the integration of approximately 20 students from different semesters and an international working group, in the moment of teamwork, everyone was able to contribute with their critical thoughts and creativity.

The prototype was developed in a conducted experiment, but it was not validated with the children of the collectors, who are the target audience, due to the social isolation imposed because of the COVID-19 pandemic. It is also necessary to validate the prototype with the waste pickers' children in the future, in order to make the app as intuitive as possible for them. However, the app was validated by the PSP5 team, that was responsible for the quality control of the prototype.

The work was developed in the relevant and authentic context of community partnerships in the real world challenge of waste disposal process. This is a fertile ground that fostered the development of PBL in terms of proposing a tool to help waste pickers acquire financial literacy. This context provided triggering points to be reflected by students in order to design a feasible Project, in terms of identifying what were the users' requirements, what questions should be answered in the case, potential solutions, comparative studies, efficient brainstorming and discussions.

Thus, students were able to develop important skills as critical thinking while proposing feasible solutions to user´s needs, communication via formal means with projects stakeholders as well as a lot of freedom and creativity while proposing software requirements and capturing the state of the art via collaborative research of existing solutions. Teachers and tutors were able to apply constant feedback and revision via a set of group presentations that took place in three parts of the semester, helping evolve students' outcomes via public presentations.

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Project Based Learning during the COVID-19 Pandemic: Experiment Reports of Initiatives in Computer Engineering

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Abstract

The COVID-19 pandemic caused profound impacts arising from a traditional on-site teaching model rupture and demanded distance learning for Engineering students, who faced additional challenges and opportunities for practical activities with physical components such as Internet of Things projects. As an alternative to standardized synchronous tests, Project Based Learning (PBL) was employed in this context to engage students in the social distancing context. This paper presents experiment reports of PBL application for the Polytechnic School of the University of São Paulo's Computer Engineering curriculum in 2020: two undergraduate courses (third year's Digital Laboratory II, fifth year's Laboratory of Software Engineering II), scientific initiation (short-term research project of smart meter for third year student), and capstone project (one year project fifth year student regarding smart home monitoring). In all courses, at least a Master of Science student acted as co-advisor or graduate teaching assistant. When combined with remote labs, home labs and virtual labs, PBL could engage students and make practical activities happen during the pandemic. The students took an active part in the projects, working with stakeholders and raising demands for tools usage.

Keywords: PBL; Computer Engineering; Internet of Things; Remote Lab.

1 Introduction

Social distancing and the consequences for education are subjects for continuous reflections regarding the way we evolve techniques and methodologies for teaching. It holds true for Engineering students: they must learn concepts, exercise them, and discuss their applications in the context of a real-life scenario. The situation caused by the Covid-19 pandemic created many touching points in education themes, especially regarding virtual interactions. In this paper, we describe the following experiences in detail: the first one regards a digital circuits lab named "Laboratório Digital II" applied for third-year students; the second one describes a scientific initiation, a short-term research project for a beginner Engineering student; about the third report describes a Software Engineering Lab, named "Laboratório de Engenharia de Software II"; and the last study case regards a Engineering capstone project where technologies and methods are presented by advisors and co-advisors to let student teams obtain consistent technical and business orientations.

Some lines of thought were fundamental to develop these education study cases:

1. Line of Thought 1: Collaboration teams with professors, students, technicians, and staff teams discussing the importance of the traditional way to teach (Hayashi, Arakaki, 2020d);

2. Line of Thought 2: Real-time data and actions using electronic sensors, actuators and other digital tools to improve the virtual platform to immerse students in their activities inside the lab instruments. In this case, considering four roles: students in pairs, each in their home; professor to assist, help and monitor learning results; the lab pieces of equipment and components accessed remotely; and technicians for supporting all activities (Hayashi, 2020a), (Hayashi, 2020b)

3. Line of Thought 3: Similar to the previous item, the Internet of Things was fundamental here. Students created innovative projects using various types of sensors and actuators, Internet connections, cloud

processing resources to support smartphone applications as evidence of digital transformation results, and providing an experience resembling an augmented reality (Hayashi, 2020c);

4. Line of Thought 4: Application of remote lab for simple experiments would be helpful, but solving practical problems was the mainstream directive to engage teams. They were strongly oriented to search and get real situations of people in their day-by-day routines. This line of though is aligned to the Problem Based Learning method (Hayashi, 2020e);

5. Line of Thought 5: Value proposition was one of the main aspects of inspiring, creating, and executing learning activities. As a result, all projects had to show what and how to add value for people (Hayashi, 2020b).

Figure 1 presents a timeline of the learning initiatives presented. All Lines of Thought cited here created engagement from students. In the lab activities, they were motivated by using canvas to improve value proposition of their projects (Osterwalder, 2019). Significant results in terms of project quality by applying immersive activities using IoT in remote lab environment. In their final course work, innovative teams' awards are evidence of marks obtained by combining these lines of thought. The following items present more details.

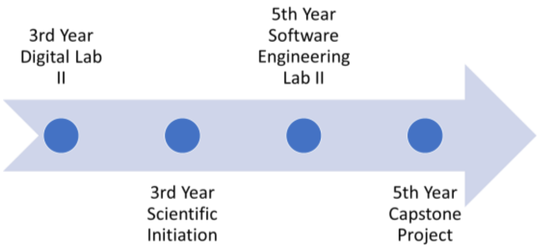

Figure 1. PBL initiatives during social distancing for Computer Engineering in 2020.

2 Prior Work

The knowledge associated with Internet of Things (IoT) technology which enabled remote monitoring and control in the social distancing context is a result of continuous efforts. In this section, prior work related to IoT is presented so that the reader is introduced to the infrastructure and tools employed in the 2020 PBL initiatives for Computer Engineering.

2.1 OKIoT – Open Knowledge Internet of Things Project

The Open Knowledge Internet of Things Project (OKIoT) is an open-source initiative for capstone projects based on IoT technologies. OKIoT aims to make IoT accelerators built in capstone projects freely available and highlights how Software Engineering methods could be used to specify and model IoT systems.

The timeline in Figure 2 presents 10 projects from 2016 to 2019:

1. CerveJá (2016): brewery automation project with mobile application and cloud-centric IoT architecture to automate brewery process at home. Group of three undergraduate students for microprocessors course. Communication based on HTTP requests and cloud monolithic architecture.
2. ElderAid (2016): elderly monitoring project with IoT modules with alert functionalities deployed locally and in the mobile device (via cloud communication) for gas leakage detection and SOS button. Group of four undergraduate students for Software Engineering II course. Communication based on HTTP requests and cloud monolithic architecture.
3. Hedwig (2017): smart home project with lightning, access control, kitchen and aquarium automation, with a fault-tolerant architecture with web interface, local and cloud back-end services. Group of four undergraduate students for capstone project. Communication based on HTTP requests, MQTT, and a fault-tolerant architecture.

4. Smart Home (2018): integration with commercial sensors and controls with radio frequency communication of 433 MHz, integration with Google Home and Alexa conversational interfaces in smart speaker devices. Communication based on HTTP requests with a fault-tolerant architecture.
5. Shared Garage (2019): with the lack of parking spaces in large urban centers, the proposed solution was to enable residential garage sharing with mobile application integrated to access control IoT module. Group of two students for capstone project.
6. Thermal Comfort (2019): motivated by the increase in the elderly population in Brazil, the project aimed to provide thermal comfort with an intelligent shower customized to each user. Group of two students for capstone project.
7. Anomaly Detection (2019): detection of outliers based on data streams from IoT sensors deployed in a smart home. The objective was to enhance residents' safety. Group of two students for capstone project.
8. Smart Home for Elderly (2019): automated reminders of medications for elderly, and proposal of open smart speaker architecture to enhance performance of conversational interfaces for smart TV usability enhancement, integrated with mobile application and open-source smart speaker based on Raspberry Pi. Group of three students for capstone project.
9. Energy Awareness (2019): voice assistant integrated with IoT devices for real-time monitoring and control, with suggestions from prediction algorithms to increase energy awareness at home. Integration with conversational interfaces and smart TV dashboard. Group of two students for capstone project.
10. Access Control for Airbnb (2019): access control module to increase usability of home sharing with fault-tolerant architecture.

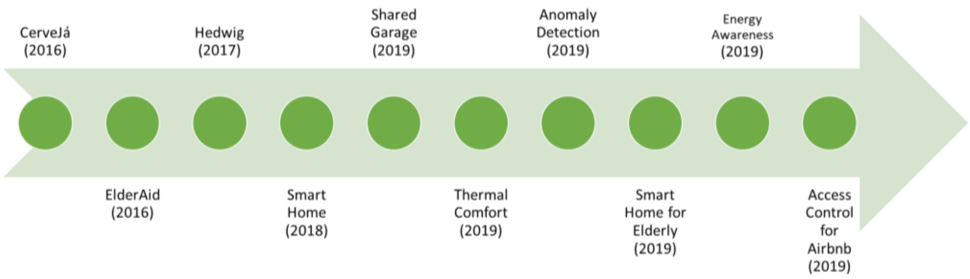

Figure 2. OKIoT Projects Timeline from 2016 to 2020.

For detailed description of available resources and projects up to 2019, please refer to (Hayashi, 2020a).

Some investigations on Software Engineering methods applicability to enhance quality attributes of IoT architectures can be found in (Hayashi, 2020b).

2.2 LabEAD – Remote Lab for Engineering

LabEAD is a series of initiatives to make remote teaching of laboratory subjects feasible for Engineering courses. In this paper, we present the LabEAD in the context of a Digital Laboratory course. Figure 3 presents a high-level concept of the LabEAD concept. Each student in their own residence can access the lab benches by connecting with an IoT platform, using their own smartphones and computers.

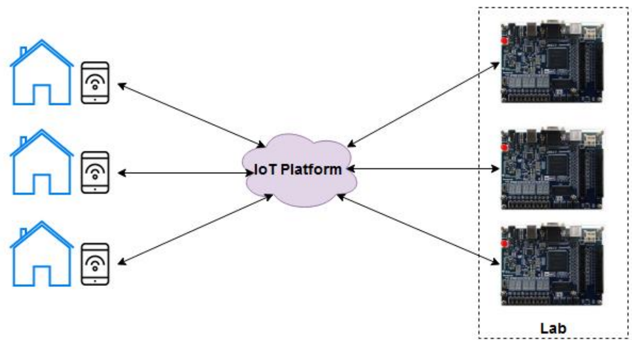

Figure 3. LabEAD high-level concept.

We decided to use Blynk IoT as the IoT cloud platform, but any other platform could be used, if the required changes are made in the source code. Each student needs to download the Blynk app in the Google Play/App Store and then use it to send commands to the lab bench. An IoT architecture is built in the lab using the FPGA board, which is the core of the Digital Laboratory course, an ESP8266 component, which has a Wi-Fi module included and some input/output expansion devices. The physical assembly is presented in Figure 4.

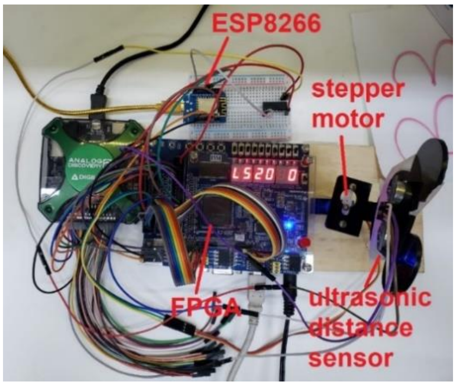

Figure 4. LabEAD physical assembly.

The project source code is available in: https://github.com/vthayashi/labead-labdig.

The first results were presented and published in (Hayashi, 2020d) and (Hayashi, 2020e).

3 Experiment Report A – Undergraduate Courses

3.1 Digital Laboratory II

The Digital Laboratory II it is a discipline offered to the third-year students. The students work in groups with a full hardware development cycle using a hardware description language (HDL) and a FPGA board.

The cycle starts with the project specification, where they need to identify which hardware components are required to implement the requested circuit, like logic gates, registers, multiplexers, and other components. After the specification, they need to write the project source code with the HDL than test the code using simulation tools like the ModelSim. This first half of the cycle the students need to make prior to the class, submitting a report to the professor with results. In the class they continue the cycle, compiling the code using the FPGA board development proprietary software, generating an output file called bitstream, then the bitstream is loaded in the FPGA board, making the FPGA behave like the circuit described. For the last part, the students need to test the circuit, sending different input signals to the FPGA and checking if the output signals are correct. If any inconsistence is verified, they need to debug the project, which can take a large portion of the class time.

In the 2020 offering, we had to adapt the course to use the LabEAD, allowing the students to interact with the FPGA board and other components, such as sensors and actuators, while respecting the social distancing protocols (due to the COVID-19 pandemic). That was possible with teachers, MSc students as monitors, course students, who all acted as stakeholders and the lab technical personnel. In addition, we used Google Meet as the videoconference tool and AnyDesk as the remote access tool to permit the students remote access to the lab computer machines.

The last half of the course classes is always dedicated to a project. The groups freely choose ideas related to the course concepts. The LabEAD allowed the students to integrate components in their residences with the FPGA board in the lab, giving more variability and possibilities to the projects. Table 1 presents 7 projects of Digital Laboratory II in the 2020 offering with 14 students. The detailed students and teacher's perceptions regarding the discipline offering were presented in (Almeida, 2021).

Table 1. Digital Laboratory II Projects.

Project Name	Description	Students
Lixeira inteligente	An IoT integrated bin, capable to communicate with a command central and track the empty fraction of its volume	2
Dispensador digital de álcool em gel	Automatic alcohol gel dispenser with a web control panel, where the owner can check the alcohol quantity inside the dispenser	2
Smart Home, detecção e ação contra incêndio	IoT platform to detect fire inside houses and act against it	2
Sonar mouse	Mouse developed with ultrasonic sensors, which receives hand movement input to move the cursor	2
Machine Learning FPGA	Neural network implemented inside the FPGA to predict stock market behaviour	2
Projeto Moisés	Garbage collection to be used inside rivers	2
Rega de plantas inteligente	An IoT platform to measure Earth humidity and automatically water plants	2

3.2 Laboratory of Software Engineering II

The Laboratory of Software Engineering II was designed to resemble a professional environment, with Master of Science student and Professor as Coordinators, and students grouped in squads, and each group has the freedom to choose a topic of interest to apply Software Engineering methods in the specification and documentation of such projects. The students are in the last year (fifth), and most of them work in entry-level positions in software companies.

The course consists of 15 weeks, with initial presentations of 15-25 minutes regarding theoretical concepts and references, and 15 minutes meeting with each group. While one group was in a meeting, the other ones could work in the project. This work method enhanced students' autonomy and proactiveness and could be applied in face-to-face and remote alternatives.

Additional integration challenges emerging in the physical distancing context could be solved with software engineering methods such as architecture specification, simulations and mock-ups, unit tests, and integration tests. A key aspect after the course turned remote was communication, which was facilitated due to videoconference and project management tools (e.g., Google Meet, Trello, Jira, GitHub). The students operated fully remote from their residences, and integrated mobile applications and cloud back-end services with agile methods in an iterative manner: each week presented a functional project deliverable.

The classes were organized as follows:

1. Digital Transformation and technology trends for project motivation, expected results of projects, Osterwalder Value Proposition Canvas for project definition.
2. Software specification concepts (e.g., non-functional requisites), Collaborative development (e.g., Trello, Git).
3. Software architecture concepts and modelling.
4. Software architecture tactics for quality metrics trade-off analysis.
5. Study cases of software architectures.
6. First project documentation deliverable.
7. Microservices architecture.
8. Serverless computing.
9. Agile methods.

10. Project sprint mapping.
11. Tests and Quality metrics.
12. Software system evaluation.
13. Project implementation.
14. Project implementation.
15. Final project demonstration using Google Meet, with documentation in a GitHub repository.

Table 2 presents the 5 projects of Laboratory of Software Engineering II in the 2020 offering with 13 students.

Table 2. Laboratory of Software Engineering II Projects.

Project Name	**Description**	**Students**
Estágio_PCS	Internship system that facilitates job search, with integrated chatbot and automated digital signature to enhance usability in the remote work context.	3
EVacina	Vaccine platform to reduce manual labor by digitalizing vaccine information. The mobile application scans codes present in the vaccine and matches location information before registration in the database. It also notifies users of ongoing vaccine campaigns.	2
Ipet	Animal monitoring platform that uses IoT camera to monitor animals (e.g., cats and dogs) at home, designed as a social network for pets.	3
NLP	Use of Natural Language Processing models to cluster and classify product feedback opinions.	1
Petfinder	Animal finding mobile application that uses image recognition algorithms to ease lost animal search. Users can look up for their lost pets, and register found pets in the platform.	4

4 Experiment Report B – Scientific Initiation

A Scientific Initiation is a short-term research project whose objective is to enable undergraduate students learn and practice the scientific method, guided by advisors.

In this case, the advisor was a Professor and the co-advisor was a Master of Science student. The advisor was responsible by providing research guidelines, and the co-advisor assisted the third-year undergraduate student in practical matters such as Arduino programming and serial communication.

The scientific initiation occurred in four months (from April to July 2020), and was comprised of:

1. Study of existing smart meter based on one-hour interview with specialist from Federal University of ABC, and papers found in the literature (Amaral, 2014; Hayashi, 2020c).
2. Familiarization with tools required for the project: Fritzing (Knörig, 2009) for hardware module design and Arduino IDE (Fezari, 2018) for Arduino Mega programming.
3. Development of low-cost smart meter with Arduino Mega. Tests in home environment with fan and light bulbs. Data registration in csv file.

The resulting prototype is presented in Figure 5.

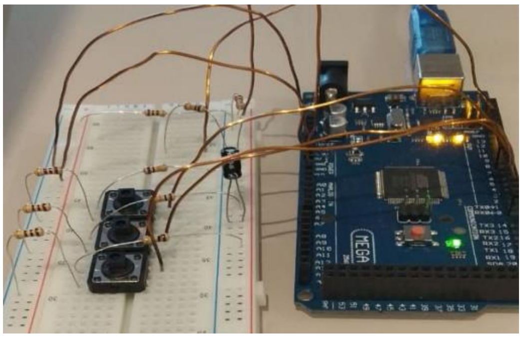

Figure 5. Low-cost smart meter prototype with Arduino Mega proposed in the scientific initiation.

The whole process was performed in a remote manner. The main challenges regard communication and physical device debugging. In some videoconferences with the undergraduate student, the co-advisor used remote access to desktop present in the undergraduate student home, and video streaming to verify if the prototype was connected properly. Additional project overhead was also added due to material delivery.

As a supervisor, some comments about this practice learning work: the student has done an excellent job: hardware circuits, local programming modules, and Internet connection supported considerable practical experience. Resilience was a soft skill capability developed by the student while facing challenges. The results presented in a workshop to students working as interns in companies received a good impression from the academic staff team that supports academic-industry relations.

5 Experiment Report C – Capstone Project

A capstone project was performed from February 2020 to December 2020, with a Professor as the advisor, and the Master of Science student as a co-advisor. The fifth-year undergraduate student was responsible for project specification, implementation, and documentation.

One of the project objectives was to build a smart home monitoring infrastructure based on Arduino, Raspberry Pi and ESP8266 IoT module with built-in filesystem and Wi-Fi communication. The ESP8266 with datalogger capabilities used was a result of previous capstone project of the co-advisor and was used in this project as an accelerator. The fifth-year undergraduate student implemented the Arduino Mega interfaces with sound, motion, ultrasonic, and temperature sensors, and the middleware deployed in a Raspberry Pi device, which transferred data in real time from the testbed to a cloud back-end.

An ultrasonic sensor deployed in the smart home, and the prototype with sensing module (Arduino Mega) and datalogger module (ESP8266) are presented in Figure 6.

The data collected in the smart home testbed was integrated with the cloud by the middleware deployed in a Raspberry Pi 3.

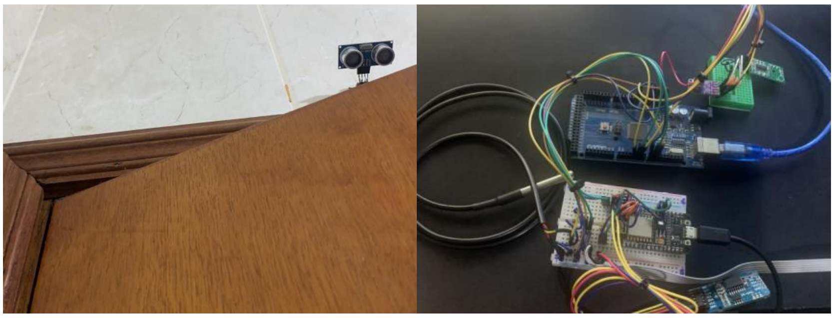

Figure 6. Ultrasonic sensor installed in smart home (left), and prototype (right) of capstone project.

Due to the COVID-19 pandemic, the capstone project was performed remotely from March to December 2020. Only initial presential meetings could be performed in February 2020. The main challenges regard testbed prototype debugging. Remote access was performed by co-advisor in the undergraduate student desktop connected with ESP8266 and Arduino devices.

The use of previous results from a capstone project (i.e., the ESP8266 datalogger module) showed the opportunity of a Master of Science co-advisor supporting future capstone projects. The deployment in a real smart home environment could be performed even in the social distancing context.

As a supervisor, some comments about this project: thinking and applying digital solutions to health in a capstone project were relate to immense opportunities. The Internet of things, cloud computing, and real-time monitoring combined to add value to people with special needs related to diabetes. The student involved constructed a tremendous professional portfolio, for sure.

6 Conclusion

The present paper described how remote practical activities were conducted in the COVID-19 pandemic scenario for the Computer Engineering at Polytechnic School of University of São Paulo in Brazil.

Internet of Things knowledge and expertise from Master of Science student (co-advisor and teaching assistant) and professor acquired from 10 projects from 2016 to 2019 were used to propose Project Based Learning (PBL) approaches in two undergraduate courses, one scientific initiation, and one capstone project in 2020.

In 2020, a total of 14 projects were executed by 29 students: 7 projects from third year´s Digital Laboratory II, 5 projects from fifth year´s Laboratory of Software Engineering II, 1 project in scientific initiation, and 1 capstone project. The PBL could engage Computer Engineering students in the social distancing context by presenting themes such as Sustainability, Healthcare, Smart Home (Safety and Automation), and Remote Work. Some students went beyond, and integrated emerging technologies such as Machine Learning, Cloud Computing, Mobile, Internet of Things and Natural Language Processing in some projects.

It demands considerable work to build new projects with innovative applications and high technical quality based on knowledge obtained in previous projects. However, we hope that by sharing how it was accomplished in the Computer Engineering using Internet of Things technologies, this idea can be expanded. The Project Based Learning approach showcased in the 14 projects executed in 2020 might be the conceptual basis for such future work.

The COVID-19 presented challenges to Engineering Education, but also opportunities to innovate in remote learning. Considering the efforts presented in this paper, the authors advocate that when combined with remote labs, home labs and virtual labs, the Project Based Learning can engage students by letting them integrate emerging technologies into their projects and choose themes of interest. The projects could create the situations and challenges necessary for practical knowledge, initially threatened by the limitations of physical access to labs during the pandemic in 2020.

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CDIO and Biomimicry: a case of study of analysis of the enhanced structural masonry interlock with the nacre interlacing solution

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Abstract

This article seeks to discuss possible contributions of addressing the environmental issue as an optional standard for the Conceive, Design, Implement and Operate - CDIO methodology. In turn, the environmental approach was based on Biomimetics in which models of nature serve as inspiration for the design of products and processes to solve human problems. In this article, the development of a students' project of the civil engineering course carried out in an optional course at PUC-SP with the union of the methodologies of CDIO and Biomimicry will be detailed. The general objective of the optional course was to create a Biomimetic engineering solution: students should choose a problem to be worked on and, from that, they should seek inspiration in nature through analysis of morphological, physiological, anatomical characteristics of living beings or even in phenomena nature to develop the conception of your project. The project described here adopted as an object of study the improvement of the interlocking of structural masonry with the use inspired by Nacre: from the analysis of Nacre's morphology, the students sought to reproduce the interlocking characteristics of this material that would influence its resistance. Through the union of CDIO and Biomimetic methodologies, students had the possibility to develop research and prototyping skills, competences, hypothesis testing and product validation. It was possible to understand in practice how the concepts of physics, mechanics of solids and strength of materials are applied to the prototype. More than the inclusion of the issue of sustainability in engineering education and in the 12 CDIO standards, inspiration in nature can assist in the development of research and innovations for engineering products, processes and systems.

Key words: CDIO Standards, Biomimicry, Masonry interlock improvement, Sustainability.

1 Introduction

This article seeks to discuss possible contributions of addressing the environmental issue as an optional standard for the Conceive, Design, Implement and Operate - CDIO methodology. In turn, the environmental approach was based on Biomimetics in which models of nature serve as inspiration for the design of products and processes to solve human problems.

The context of this proposal is connected to the evolution of the 12 CDIO Standards: originated in the 1990s in the Aeronautics and Astronautics program at Massachusetts Institute of Technology - MIT, the CDIO methodology emerged to meet demands for a teaching-learning method that engineering students should be able to work on theoretical knowledge and, simultaneously, they could develop a set of soft skills. In 2001, version 1.0 of the CDIO Syllabus was developed and, later, in 2004, the international CDIO initiative was created with the participation of 10 schools. In 2005/2007, 12 standards were proposed for the implementation of the methodology. These standards have undergone a reformulation in 2014 giving rise to Syllabus 2.0 followed by additions in 2016, generating the version of Syllabus 2.1. According to MALMQVIST et al, "*The standards define the distinguishing features of a CDIO program, serves the guidelines for educational reform, enable benchmarking with other CDIO programs and provide a tool for self-evaluation-based continuous improvement*". (MALMQVIST et al, 2020, p.48)

In 2017, discussions for Syllabus 3.0 have emerged: for Malmqvist et al. (2017, p. 21) once external context of engineering education has evolved, the CDIO approach must be evolved as well. In this version of Syllabus comes the proposal to create "optional CDIO standards", which would be added to the original twelve standards, now called "core CDIO standards". (apud MALMQVIST et al, 2020, p. 48). Both optional and core

CDIO standards have come to address the environmental issue in a perspective of enabling future engineers to work with sustainable lifecycles for products, processes and systems.

Since 2016, the CDIO methodology has been applied in conjunction with Biomimetics in an optional undergraduate engineering course at the Pontifical Catholic University of São Paulo - PUC-SP. Previous results have shown to be very promising in instigating the creation of innovative and sustainable engineering solutions. (RAGGI, MUNHOZ, & NORIEGA, 2018) According to Janine Benyus "*Biomimicry is a new science that studies nature's models and then imitates or takes inspiration from these designs and processes to solve human problems*". (BENYUS, 1997, p. 6) In this article, the development of a project for students of the civil engineering course carried out in this optional course with the union of the methodologies of CDIO and Biomimicry will be detailed.

2 Scope

The general objective of the optional course was to create a Biomimetic engineering solution: students should choose a problem to be worked on and, from that, they should seek inspiration in nature through analysis of morphological, physiological, anatomical characteristics of living beings or even in phenomena nature to develop the conception of your project.

In the last semester of 2020, the course was offered to a class of 16 civil engineering students. They were divided into 4 groups and each chose a working problem. In a period of approximately 4 months, students should conceive, design, implement and operate a prototype, seeking in nature the inspiration to solve the problem. This article describes the study developed by one of these groups.

The project described here adopted as an object of study the improvement of the interlocking of structural masonry with the use inspired by Nacre: from the analysis of Nacre's morphology, the students sought to reproduce the interlocking characteristics of this material that would influence its resistance.

3 Teaching-Learning Methodology

The teaching-learning methodology was structured through the project lifecycle proposed by CDIO, passing through the stages of Conceive, Design, Implement and Operate.

During the 2nd semester of 2020, the students conceived the project by researching the characteristics of constructive pathologies and possible solutions to be adopted inspired by beings and phenomena of nature through Biomimetics.

After developing the scope of the proposal, activities were oriented towards the realization of the prototype project. Given that the entire prototyping stage would be carried out in the midst of the COVID-19 pandemic, and that access to materials and laboratories at the university were greatly compromised, students were instructed to carry out simplifications in the project in order to make their construction and testing viable. In that instance they use accessible and available resources in their own homes.

Once the design and planning of the testing stage was established, the development of a prototype for concept testing was stipulated. In this intermediate prototype, the students were able to verify the viability of their ideas and possible implementation problems.

After correcting the problems found, the students were instructed to develop the final prototype in order to carry out the implementation and operation analyzes. In view of the results obtained, students should check the potential and limitations of the prototype. The objectives of the study developed by the students as well as the motivation of this study are described below.

4 Study Objective and Motivation

According to (SAMPAIO, 2010), of the varied pathological manifestations that can appear in the structural masonry, the fissures and cracks stand out. The appearance of these pathologies can occur when fragile raw materials of ceramic, concrete and mortar blocks are subjected to tensile, bending, shearing, mortar retraction efforts, among others. The area most affected by such damage is the interlocks, which corresponds to the region with the least resistance in the set, as shown in figure 1.

Figure 1. Fissure in the interlocking of Structural Masonry retrieved from (Oliveira, 2016, p. 7)

This study aims to seek solutions to reduce the occurrence of cracking and cracking pathologies, ensuring improvements in the interlocking of structural masonry. It starts from the concept of Biomimetics, which according to BENYUS (1997) consists of science that studies the solutions of nature in order to imitate them or be inspired to solve human problems.

After researching different solutions from nature, it was found that the morphology of the mollusk shells allowed the optimization of their resistance. The main characteristic observed was the existence of interlaced plates called nacre in the shells, as shown in figure 2. According to MATER (2005), nacre has an interlacing that allows it to increase its resistance. It is an iridescent material composed of aragonite, with fixation carried out by organic layers on its surface consisting of protein, guaranteeing the flexibility of the material and the union of the interlacing. In tests, it was found that such a set guarantees a resistance to nacre 3000 times greater than that obtained in aragonite alone.

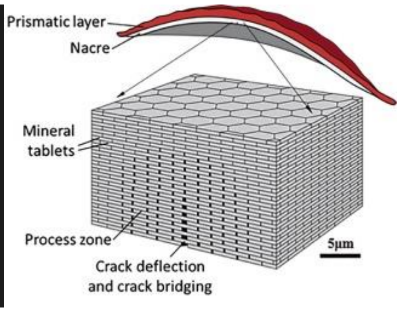

Figure 2. Nacre example retrieved from (EWA et al., 2019) and Figure 3. Morphology of Nacre retrieved from (IDRIS; FRANCOIS, 2016, p.390)

In percentages of constitution, Nacre has 5% of its weight composed of organic material of proteins and polysaccharides; the remaining 95% consist of hexagonal-shaped aragonite, stacked in a staggered arrangement, similar to the structural masonry block wall, as shown in figure 3, with the plates twisted in relation to each other by 5%, with sinking overlapping the neighbor by 20%" (MATTER, 2005).

MATTER (2005) complements that the composition and constitution of the nacre guarantees resistance both to the efforts of traction and compression, as well as resists catastrophic failures that in other structures result in the propagation of cracks. Its composition has greater tenacity, that is, it needs more energy to generate fractures or plate breakage. And even if for some reason it starts a crack, the hexagonal shape of its parts will make transmission difficult.

Based on this principle, the improvement of structural masonry was sought through the reproduction of these morphological characteristics. We sought to apply such properties to prototypes, the description of which was elaborated below.

5 Work Plan

5.1 Materials and Methods

In order to carry out tests on a model inspired by nacre, some prototypes were proposed for experimentation, using materials of easy access and handling listed below on table 1:

Table 1. List of using materials

List of using materials	
• Plaster;	• Scale to measure loads;
• Gray adhesive cementitious mortar;	• Hexagonal Ice Forms (1.25 x 1.25 x 2 cm);
• Adhesive AC III White mortar;	• Rectangular Ice Shapes (1.5 x 1 x 1 cm);
• Water;	• Strings;
• Wooden base;	• Spatulas and sandpaper for blocks and arrangements;
• Sledge hammer;	• Ruler for measuring columns.
• Books, and weights to serve as cargo;	

Once the research was carried out in the context of the COVID-19 pandemic, due to the limitations of access to laboratories and materials, the choice of accessible raw materials was chosen amid a lack of resources. In this context, plaster was used to shape the blocks as a representative of the bricks used in Structural Masonry. Plaster was chosen because it is a water-repellent material, easy to access and handle, in addition to quick drying.

The volumetric trace used was 1: 7 of water and plaster, with the aid of ice molds in hexagonal and rectangular shapes. Blocks of an equivalent area of 1.5 cm^2 were built. With the dry blocks, hand-held fittings were made in the hexagonal blocks: hen subjected to compression, the blocks are "tied" providing greater resistance to the structure in the same way as the entanglement observed in the nacre, as shown in figures 4, 5 e 6.



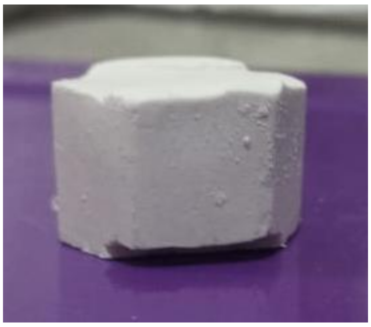

Figure 4. (left) Molding of rectangular blocks and Figure 5. (center) Molding of hexagonal blocks Figure 6. (right) Hexagonal block

Two systems for comparison were set up, both measuring 10 x 10 x 8 cm under the same wooden base: (I) rectangular blocks, imitating the shape of common bricks, and (II) hexagonal blocks inspired by nacre Morphology. Both systems were grouted with 1: 2 mix mortar with water and cement, as can be seen in figure 7.

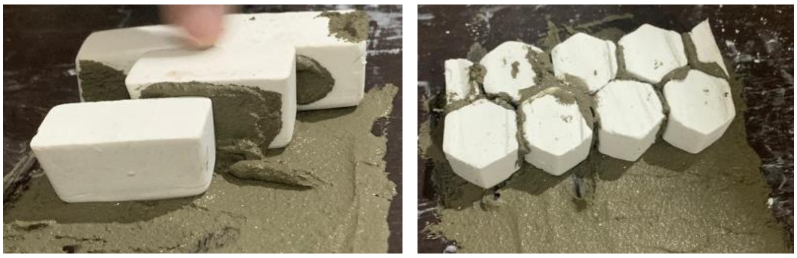

Figure 7. Systems assembled with hexagonal and rectangular blocks.

Resistance tests were started on both systems for comparative analysis.

5.2 De Description of Experiment

5.2.1 Phase 1 of the Experiment - Concept Test Prototype

The prototypes of rectangular and hexagonal blocks were assembled using the gray adhesive mortar. From this, two types of tests were performed: one with static load under the system, and the other with dynamic load through free fall, as shown in figures 8, 9 and 10:

Figure 8. Assembled Prototypes (left) Figure 9. (center) Static Load Test and Figure 10. (Right) Mobile Load Test

For the test of resistance to static efforts, school materials (books and notebooks) were used as a load, juxtaposed on the molded system, totaling a weight force of 200N. As a result, it was noticed a crushing in the mortar of the system composed of rectangular blocks, however, both systems resisted well, without showing signs of rupture.

In turn, dynamic load tests were carried out with the aid of a 1.2Kg sledgehammer (approximately 12N). The sledgehammer initially at rest was tied to a string and aligned vertically with the molded systems. In sequence, it was repeatedly launched in free fall with varying height, obtaining the following results shown in table 2:

Table 2. Results obtained in the first experiment with dynamic load

Distance (cm)	Rectangular Blocks System	Hexagonal Blocks System
25	No visible effect	No visible effect
30	No visible effect	Beginning of cracking in the mortar, with the blocks still interlocked
35	Crushing and deformation of the system	Break of the system, but without breaking the blocks
40	Break of the system with breaking the blocks	-

Phase 2 of the Experiment - Final Prototype

After the dynamic load tests of the first phase of the experiment, possible flaws in the molded system were analyzed and proposals were made that could improve the performance for the next phase.

In the assembly of the new prototypes, the improvement occurred through the interlocking, which was rethought from the arrangement of the blocks in the mortar. Also, it was used the AC III White Flexible Adhesive mortar, with a higher degree of elasticity than that previously used in phase 1, with a function similar to the protein structure existing between the nacre plates, as shown at figures 11 and 12.


Figure 11. New hexagonal prototype and Figure 12. New rectangular prototype

Following the same test method with dynamic load, the following results were shown in table 3:

Table 3. Results obtained in the second experiment with dynamic load

Distance (cm)	Rectangular Blocks System	Hexagonal Blocks System
20	No visible effect	No visible effect
25	No visible effect	No visible effect
30	No visible effect	No visible effect
35	The first cracks appear	Flattening at its bottom base
40	It remained stable	It remained stable
45	It remained stable	It remained stable
50	Appearance of more significant cracks	It remained stable
55	It remained stable	It remained stable
60	It remained stable	Small cracks only at the ends
65	Larger size cracks	It remained stable
70	Partial system disruption occurs	It remained stable
75	A complete disruption of the system occurs	It remained stable only with partial rupture on the sides

Figure 13. Dynamic Load Tests / Result System with hexagonal blocks and System with rectangular blocks

The tests continued until the mallet was launched at a height of 100 cm, but the system inspired by nacre morphology, with the hexagonal blocks, remained stable and did not break completely. In sequence, analyzes were made on the results obtained.

5.3 Result Analysis

In the first phase of testing, the system composed of rectangular blocks proved to be more effective than the hexagonal ones. It is believed that this fact occurred due to the lack of horizontal interlocking in the system inspired by nacre, where the arrangements of its blocks were just stacked on top of each other. In addition, the inserts made in the hexagonal shaped blocks were made by hand due to lack of resources, which made them irregular and not uniform.

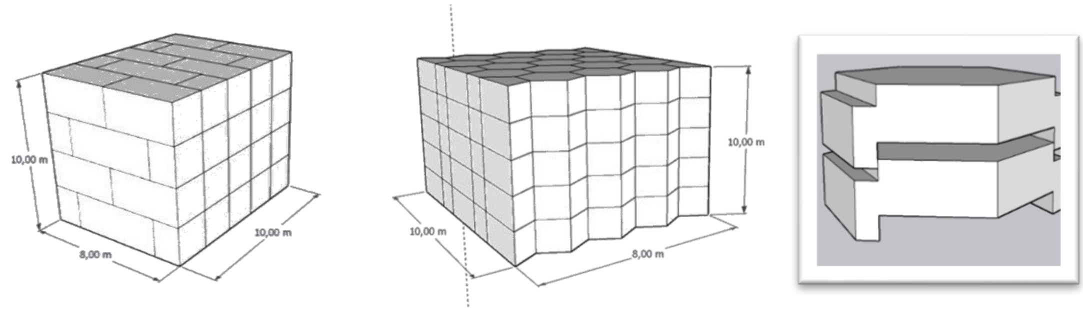

Figure 14. Assembly of phase 1 prototypes

In this way, the means of assembly and molding used were studied, so that new tests could be carried out, as well as the implementation of improvements. In addition to the use of AC III mortar with a high degree of elasticity, in the interlocking of the hexagonal blocks the fittings were not molded, thus directing a greater focus to the arrangement of the interlocked blocks.

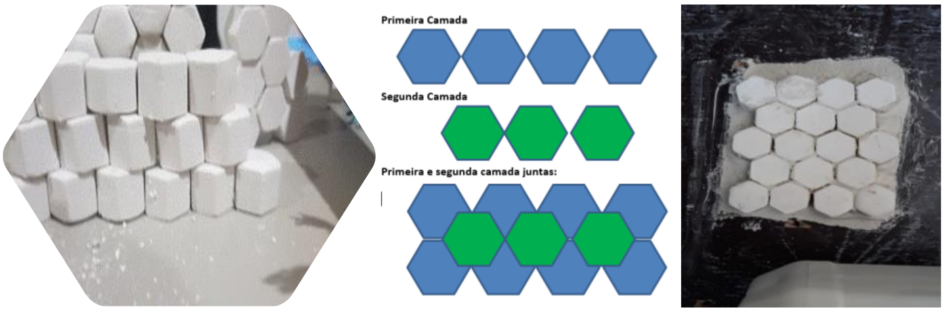

Figure 15. Application of improvement in phase 2

In the results of the second phase, it was possible to notice that the system inspired by nacre's morphology showed an improvement in its performance, becoming more resistant compared to the rectangular block system.

Despite this, it is important to consider the scarcity of resources for research and the lack of reliability in the results, considering that both systems were molded by hand, together with the load tests that were not carried out on suitable equipment, due to the lack of access to laboratories.

6 Analysis of Potentiality and Limitations

The main limitations of the study are found in the manual execution of the block samples, lack of access to materials managed to reproduce the elasticity generated by the protein layer of connection between nacre and the impossibility of using laboratories to create a controlled and reliable environment for the performance comparisons.

However, despite these limitations, it was possible to see a significant increase in the resistance of the hexagonal blocks in the second test phase (the beginning of the break occurred with strikes 15 cm higher than in the case of the rectangular blocks). The solution presented a satisfactory result, demonstrating that there is potential for improvement in the model through greater technological control in the prototyping and testing phases.

7 Continuity Plan

Through the union of CDIO and Biomimetic methodologies, students had the possibility to develop research and prototyping skills, competences, hypothesis testing and product validation. More than that, it was possible to understand in practice how the concepts of physics, mechanics of solids and strength of materials are applied to the prototype.

If further studies show an increase in the resistance of a set of hexagonal blocks connected by flexible structures, the application of these blocks in civil construction could optimize the use of construction materials, implying a reduction in costs and in the environmental impacts of civil construction. Research may be proposed as a result of this initial study, with the use of construction materials creating hexagonal blocks used with mortars with high elasticity.

8 Conclusion

Due to processes of natural selection and evolution, morphological, physiological and anatomical characteristics of living beings or even the very balance of biotic and abiotic systems can become a repository of knowledge. More than the inclusion of the issue of sustainability in engineering education and in the 12 CDIO standards, inspiration in nature can assist in the development of research and innovations for engineering products, processes and systems.

From the teaching point of view, it is believed that the union of CDIO and Biomimetics methodologies can contribute to the generation of meaningful learning and environmental awareness. The creation of a product based on a specific problem, and which is solved through Biomimetics allows the valorization of the environment not only as a source of natural resources, but also as a repository of knowledge. At the same time, through the construction of the prototype, students transform abstract knowledge related to the exact sciences into tools for the stages of design, implementation and operation.

In turn, from the point of view of learning, it is believed that two points deserve to be highlighted: (I) the limitations imposed by the Covid-19 pandemic and (II) the CDIO learning methodology. In relation to the limitations imposed by the pandemic, the change from the face-to-face classes to remote activities demanded greater focus and dedication on the part of the students. Despite this, the use of digital platforms has made it possible to shorten distances between students and teacher, enabling more agile and frequent communication. Teachers have become more accessible through digital platforms. A challenge found in this scenario was consequently the lack of access to materials and laboratories. Despite the limitations, the creativity to establish a comparative method allowed students to work with adverse conditions. In contrast, the CDIO learning methodology showed students a better way to execute and understand the results and stages of a work, in a way that is consistent with the reality of an engineering project life cycle and also giving the possibility to acquire a greater assertiveness in the results.

With these observations it can be concluded that the scenario in which the group encountered difficulties, but in return demanded from the students more dedication, patience, focus, group work, and especially more creativity. The experience acquired by the group as a team engaged students in the learning process.

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Preferred Roles of Industrial Engineering and Management Students - An exploratory European analysis

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Abstract

The European Students of Industrial Engineering and Management (ESTIEM) is a non-profit organization of Industrial Engineering and Management (IEM) students, founded in 1990 to promote the connection between students, companies, and professors by its activities and initiatives. Through its partnership with the European-funded "Professional Roles and Employability of Future EngineeRs" (PREFER) project, whose objective is to allow students to better understand what engineers do and what kind of engineers they want to be, ESTIEM started a research to better understand the preferred engineering roles of students in several universities in Europe. In the PREFER project, three professional roles for early career engineers - Product Leadership (focusing on radical innovation), Operational Excellence (focusing on process optimisation) and Customer Intimacy (focusing on tailored solutions) - have been identified. Furthermore, competencies essential to be successful in those roles have been associated with them. Based on this model, two tests for engineering students were developed including the PREFER Explore test, which identifies the preference of the engineering roles. Understanding the importance of knowing the competencies needed for future engineers, the goal of the research is to map the possible differences in regard to the preferred roles among IEM students in Europe. This paper reports the findings of the Explore test run among six universities in Europe that are members of the ESTIEM network (Lisbon, Porto, Liège, İstanbul-Boğaziçi, Eindhoven and Saint-Petersburg). From those, Bachelor and Master students in IEM were invited, regardless of their association with ESTIEM (n=179). Findings indicate that the roles preference vary inside each university, even though the population shares the same educational background, and throughout the different European universities analysed. Furthermore, it explores the potential factors influencing those preferences based on students' insights and previous research conducted by ESTIEM.

Keywords: Engineering roles, Engineering education, Industrial Engineering and Management.

1 Introduction

The transition from academic life to the labour market is difficult for most of the students and it is the responsibility of higher education professionals to ensure a smooth transition. The factors explaining this difficult transition are various and among those we can underline the fact that students have generally wrong expectations or are not aware of what they could or would like to do.

As a European network, great differences in the quality of the education were noticed and also the emphasis professors put on the preparation of their students for their future careers are different. For example, in some universities students are in contact with the industry through workshops or internships from the beginning of their studies, whereas in other students barely get in contact with the industry at the time of graduation.

Besides the general knowledge students acquire during their studies, also called hard skills, there is an increasing demand from the industry in more transversal knowledge such as communication skills, teamwork, organization, etc. - the so-called soft skills. It is often difficult for students to clearly determine which soft skills they need to acquire or improve. Soft skills are often overlooked by universities, so some students turn into student associations, junior enterprises or networks, such as European Students of Industrial Engineering and Management (ESTIEM), to develop those.

The number of reasons why engineering students need to be well-informed regarding their possible future careers is enormous. By helping young engineers to discover who they are in and by raising awareness of the different professional roles they can take on early in their career, they would be better prepared to fit the labour market requirements.

As so, the purpose of this study is to make a European analysis of the role distribution inside and between different European universities. This study contributes to the existing literature and research, as it is the first time that it is applied in a European context of industrial and management engineering.

The remainder of this paper is divided into four sections. The next section explores the existing literature on the topic of engineers' role as well as the backgrounds of ESTIEM and PREFER. Subsequently, the methodology applied to collect the data will be presented. Thereafter, the results and an analysis of those are provided. Finally, a discussion of the results and a conclusion are proposed.

2 Importance of role understanding in the engineering profession

The following section first presents an overview of the available literature on the topic of role definition in the engineering profession. Then, a general description of ESTIEM, the network which conducted this study will be provided. Third, the Professional Roles and Employability of Future EngineeRs (PREFER) project, its aim and application are described as it is used as the theoretical framework to investigate professional preferences. The section finishes by the formulation of the research questions taking into account the previously described literature and background of the study.

2.1 Literature review

The transition from higher education into the labour market is something most young graduates find difficult as they don't know what to expect and what their worth is. In his empirical analysis, Tomlinson (2007) discusses how students' orientations have an influence on the choice of their future work and employability and concludes that besides developing competencies, students also need to develop their own identity.

In the engineering field, Bennett and Male (2017) suggest that engineering students need to explore the roles of engineers and their own selves in order to be able to make the best decision for their future career. Higher education institutions recognize their responsibility in guiding students in the important decision that the first job represents (Burke et al. 2017; National Academy of Engineering 2018). Nonetheless, this is not an easy task, as demonstrated by Bennett and Male (2017), because even after the completion of their bachelor's degree, engineering students remain unaware of what they can expect for their future careers. This is further emphasized as the engineering field is often seen as technical, rather than focussing on the professional aspects of the profession (Brunhaver et al. 2018).

It may be of no surprise then that young graduates can experience a gap between what they expect and their first experience (Chan, Zhao, and Luk 2017). This gap can also, unfortunately, lead to a negative job satisfaction as demonstrated by Jusoh, Simun, and Chong (2011), who showed that communication, decision making, and motivation are three important aspects influencing one's job satisfaction.

Engineers have the possibility to enter in a wide variety of sectors after their graduation. This offers a lot of different perspectives to the young graduates but also leads to a vague understanding of their possible future career or the role they can take on when entering the labour market. Although, knowing the world of work eases the process of career decision making and job transition (Kracke, 2002; Meijers et al., 2013), research on professional roles for early engineers is scarce. The existing literature on engineers' professional roles is rare and fails to clearly address the variety of the job market. Based on a systematic literature review, Craps et al. (2020) proposed a model aiming to help engineering students understand their professional identity and to avoid the skills mismatch. Craps et al. (2020) not only expanded the literature on professional roles in engineering but demonstrated that the roles reflect the overall expectations of the work field. The model was further developed into a competency model validated in industry and education.

The concern of helping students and young graduates in finding out who they are as professionals is not new. Previous research clearly aims to help students to direct their career path, while exactly knowing what they are searching for. Based on this, the current research aims to apply the framework developed by Craps et al. (2021) in a European context focussing on industrial and management engineers.

2.2 ESTIEM

The European Students of Industrial Engineering and Management (ESTIEM), founded in 1990, brings together students in Industrial Engineering and Management (IEM) from 74 different universities in Europe, representing a total of 26 countries. ESTIEM is represented in each of these universities by a student's union including a corresponding Local Representative that makes the bridge between the local and European association. This network has the aim of connecting the students of IEM with universities, companies and institutions operating around IEM, as well as to develop them in a personal and professional way. As so, its main activities consist of events in the areas of academic, career, personal and intercultural development. ESTIEM puts a high emphasis on education and social and environmental responsibility, as well as trying to provide necessary skills and experience for students to get prepared for their future careers.

Recently, in 2020, ESTIEM started research projects focusing on IEM. The Curricula Database Project aims to classify IEM bachelor's degrees from our partner universities. In order to do so, a framework has been developed in collaboration with professors from the European Professor of Industrial Engineering and Management (EPIEM). This framework offers five main scope of areas (sciences, engineering, industrial engineering and management, management, others) and each of those are also divided into sub-areas which allow a deep understanding of the composition of IEM degrees. The Career Analysis Project aims to depict the career path of IEM graduates. A framework has been developed by merging the knowledge of one member of the ESTIEM Alumni network with the NACE framework, the statistical classification of economic activities in the European Community. Based on that, a survey was conducted in the Alumni network and analysis on the preferred career paths were made showing that IEM students adopt a wide variety of options and common patterns can be observed in some regions. The results of the current study, reported in this paper, will be interpreted within the findings of both ESTIEM research projects, the Curricula Database Project and the Career Analysis Project. We further refer to these projects as resp. academic context and professional context.

2.3 PREFER

Within the multidisciplinary engineering scenario, understanding the different profiles and competencies is a critical success factor that sets the foundations for early professional development and career growth (Lauwers, Bonte and Vanmaercke 2013).

The positive impact of acquiring this knowledge during the academic journey, as well as the gap of specific literature on the field of professional roles for engineers (Craps, Pinxten, Knipprath and Langie 2020), motivated the study and development of a model known as Professional Roles Model for Future Engineers (PREFER model) (Craps, Pinxten, Knipprath and Langie 2021), combining the preliminary models presented in previous research conducted on this subject (Spinks, Silburn and Birchall 2007; Hofland, Pinxten, Wauters and Langie 2015). The result model is presented in Figure 1.

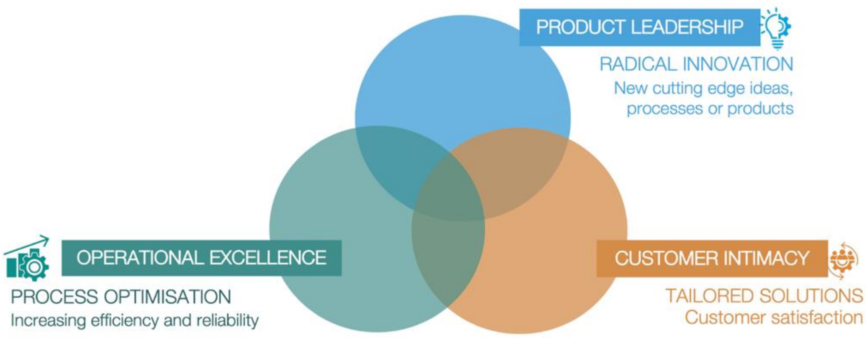

Figure 1. Professional Roles Model for Future Engineers (Craps et al., 2021).

The PREFER model describes three roles - Product Leadership, Operational Excellence and Customer Intimacy - that engineers can take on early in their career (Craps et al., 2021). For each role, industry indicated what competencies are required. The reflective instrument acknowledges that an engineering career is determined through close interactions of the identified areas instead of a mutual exclusive relationship of a single one.

Focusing on the area of radical innovation, the role of Product Leadership is associated with creativity through research and development, being the most suitable profile for students who are eager to explore new paradigms and build marketable products from scratch (Craps et al., 2021).

Focusing on the area of process optimisation, the role of Operational Excellence is associated with the design and implementation of operational processes, being most suitable for students who thrive on locating opportunities for efficiency and effectiveness gains (Craps et al 2021).

Focusing on the area of tailored solutions, the role of Customer Intimacy is associated with developing solutions for complex business environments, relying on both qualitative and quantitative aspects, being most suitable for students with strong communication skills that are capable of developing dynamic solutions (Craps et al 2021).

Based on the PREFER model, two tests were developed. The PREFER Explore test, which supports students to explore the different roles and their preference for each one of them, and a follow-up PREFER Match test, with specific guidelines for each area, which gives students feedback on their role alignment and essential competencies. In this study, the PREFER Explore test, a personal preference test, is used to identify the professional role preference of IEM students.

2.4 Research questions

The previously developed literature on engineers' professional roles and the mission of the ESTIEM network helped us to formulate the following research questions:

RQ1: What are the preferred roles among IEM students in a European context?

RQ2: Is there a relation between the academic and/or professional context and the professional role preference?

3 Methodology

A mixed methods approach was chosen as it provides a better understanding of the topic investigated (Creswell, 2009). First, a quantitative online survey was conducted. The results were mapped against the academic and professional context. A follow up qualitative part with a few participants was organised to give voice on the topic and triangulate the results.

3.1 The sample

The study was conducted in six universities associated with the ESTIEM network: Lisbon (University of Lisbon) - Portugal; Porto (University of Porto) - Portugal; Saint-Petersburg (Saint-Petersburg State University of Economics) - Russia; Liège (University of Liège) - Belgium; İstanbul-Boğaziçi (Boğaziçi University) - Turkey; Eindhoven (Eindhoven University of Technology) - The Netherlands. The universities were selected based on their location, in a way that allowed us to have two from Southern Europe, two from Eastern Europe and two from Western Europe.

Within these six universities, the spreading of the survey was channelled through the local associations in order to motivate the Bachelor's and Masters' students' community to participate in the study, regardless they did (not) belong to the local association. This resulted in the sample size displayed in Table 1, distributed according to the responses obtained from each studied location.

Table 1. Distribution of Sample Size per university included in the Study.

University	Lisbon	Porto	Saint-Petersburg	İstanbul-Boğaziçi	Liège	Eindhoven
Region	Southern	Southern	Eastern	Eastern	Western	Western
Sample Size	52	39	27	20	22	19

The participants gave their consent before taking the survey. The data were handled anonymously. Considering data-related privacy issues, information such as age or gender of the respondents, level of study and previous professional experience were not mandatorily collected within the survey.

In the second stage of the research, one bachelor and one master's student from each university were chosen randomly after taking the survey.

3.2 Data collection

Data was collected in three ways: (1) the data from an online test (PREFER Explore) provide insight in professional role preference (RQ1), (2) the data from the previous ESTIEM projects provide insights in academic and professional context (RQ2), (3) while the interviews allow to triangulate the different sources of information and confirm the accuracy of our findings.

3.2.1 Online survey: professional role preference

The PREFER Explore test, a personal preference test, was used to provide an overall perspective of role preference allowing the comparative analysis. The online survey was distributed through the local associations' social media in order to motivate the bachelor's and masters' students' community to participate in the study, regardless of their membership to the local association.

The test includes ten questions, each with three responses. Participants are asked to range the responses from most to least preferred. The online can be accessed through www.iiw.kuleuven.be/prefer and takes about 5 minutes.

3.2.2 ESTIEM projects: academic and professional context

In order to better understand and explain the results of the quantitative data collected through the survey, data collected from the previously described ESTIEM projects were used (section 2.2). The data collected in the Curricula Database project (academic context) are directly based on the publicly available course descriptions of the bachelor's degree of each university. Based on that, the courses were classified in five categories and then the respective weight of each of those categories were provided in terms of percentages. The data collected in the Career Analysis project (professional context) are coming from a survey disseminated in the ESTIEM Alumni network. The number of respondents varied from one university to another between 5 to 25 participants. Based on the survey, the number of occurrences had been computed allowing us to put each career path in perspective of one another.

3.2.3 Semi-structured interview: triangulate results

In a final stage, interviews were conducted in a semi-structured way in order to triangulate the results and enhance its credibility. Participants were shown the results of the quantitative study and the outputs of ESTIEM's research and were asked if it made sense in regard to their own experiences. Furthermore, they were asked the possible factors influencing the preferred role distributions, the effect their curricula had on the role's distribution, etc. For example, some of the questions asked during the interview were:

- "Considering the five main areas (sciences, engineering, IEM, management, others), which are the ones, according to you, that are more present in your curricula?" (showing the results of the preferred roles) "Are the following results aligned with your expectations and the curricula you follow?"

- "According to your experience, what are the most preferred career paths of the students from your university?" (Showing the results of the Career Analysis Project) "Do you see a match between those results, the preferred roles and your experience?"

3.3 Data analysis

The output of the online PREFER Explore survey is presented under the format of a table divided into columns representing each one a situation and ranking the roles from most preferred to least preferred. Those data were analysed using Microsoft Excel. A computation of the number of occurrences of each role has been done for each observation following Pinxten et al. (2020). In order to get the final output, the previous results were summed and transformed into percentages to allow an easier analysis of the results.

4 Results

The main objective of the research is to explore the differences that may exist regarding the preferred roles between each university, while also drawing some preliminary conclusions about key factors behind it, namely, the academic and professional context.

4.1 Professional role preference

The application of PREFER Explore to each university's student community resulted in the distribution of preferred roles shown in Table 2, revealing a non-uniform classification for each location.

Table 2. Distribution of Preferred Roles per University Included in the Study.

Role per University	Lisbon		Porto		Saint-Petersburg		İstanbul-Boğaziçi		Liège		Eindhoven		Total	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Customer Intimacy	13	25%	14	36%	12	44%	6	33%	9	41%	2	10%	56	32%
Operational Excellence	19	37%	15	38%	4	15%	1	6%	7	32%	10	53%	56	32%
Product Leadership	20	38%	10	26%	11	41%	11	61%	6	27%	7	37%	65	36%
Total	52	100%	39	100%	27	100%	18	100%	22	100%	19	100%	177	100%

4.2 Academic and professional context

Based on the results presented in Table 2, the abovementioned ESTIEM research, the following conclusions per university were formulated as an answer to the two research questions previously defined. It is important to mention that those findings have been confirmed by the students when conducting the interviews.

University of Lisbon, Lisbon

Similar results were found for Product Leadership and Operational Excellence. Customer Intimacy seems to be the least preferred role. Aligned with the curricula, the students are taught a majority of engineering and industrial engineering and management related courses in their Bachelors'. Furthermore, those results are in line with the fact that most of the students tend to write their Master thesis in industrial-based consultancy and service companies.

University of Porto, Porto

Operational Excellence and Customer Intimacy are the two preferred roles with similar results. In fact, despite the very big amount of Science and Engineering subjects in their Bachelors, these roles are in line with the high importance given on customization and process optimization during their Masters. Besides, after finishing the degree the majority of the students aim to work in industry or in services.

Saint-Petersburg State University of Economics, Saint-Petersburg

Customer Intimacy and Product Leadership seem to be the two most preferred roles, leaving Operational Excellence on the side. This might be related to their curricula focussing a lot on management during the first two years of their studies. Besides the general courses mixing a lot of management and industrial management topics, students have the possibility to apply those concepts in real-case scenarios through various case studies, company visits, and workshops organized by the university. Young graduates are expected to either enter consultancy firms, open a business or take on a position as project managers in the industry.

Boğaziçi University, İstanbul-Boğaziçi

There is a clear preference for the Product Leadership role followed by the Customer Intimacy. The Operational Excellence role seems to be by far the least preferred one. This can be explained by the structure of the bachelor's degree. In fact, students have highly engineering focussed courses such as engineering graphics, materials and processes in manufacturing, etc. or management courses such as economics, accounting, etc. The data regarding the level of studies were available for this university and most of the respondents were first- or second-year Bachelor students, showing the potential correlation between the amount of Engineering subjects and the tendency to prefer the Product Leadership role.

University of Liège, Liège

For these students, the most preferred role is Customer Intimacy followed by Operational Excellence and finally Product Leadership. This can be explained by the fact that the students are studying in a management school, therefore, their main subjects are courses such as accounting, marketing, economics, etc. Nonetheless, there is a great focus on supply chain management and operations research and a low focus on engineering subjects. After they graduate, most students take on responsibility positions in consultancy companies or private small to medium enterprises.

Eindhoven University of Technology, Eindhoven

There is a higher tendency towards the role of Operational Excellence and Product Leadership, leaving the Customer Intimacy role aside. During their Bachelors, students follow highly specific courses in the areas of industrial engineering and management as well as in the engineering area. The Eindhoven University of Technology puts a great emphasis on the development of new technologies, on the research and development and on the operational excellence of all the processes. Therefore, most of their young graduates enter the labour market in the industry as product development team leader, operations specialist, etc.

Comparison across regions

The following table shows the distribution of preferred roles across regions, showing interesting patterns.

Table 3. Distribution of Preferred Roles per Region.

Role per region	Southern Europe		Western Europe		Eastern Europe	
	N	%	N	%	N	%
Customer Intimacy	27	30%	18	40%	11	27%
Operational Excellence	34	37%	5	11%	17	41%
Product Leadership	30	33%	22	49%	13	32%
Total	91	100%	45	100%	41	100%

On a regional perspective (Southern-Europe), Lisbon and Porto are the most balanced ones in terms of role preferences. Another observation that can be made is the particularly low preference for the Operational Excellence role in Eastern Europe. No major conclusion can be drawn from the role distribution in Western Europe.

When analysing the overall distribution of the role preferences (Table 3), the difference between role preferences is small which can be interpreted as good because the industry needs to have the three types of engineers in order to operate efficiently. The needs of the industry change from one country to another, from one economic situation to another, from one crisis to another.

5 Discussion and Conclusion

The application of the PREFER Explore to the selected six universities spread across Europe seems to present a significant diversity of preferred roles between students, motivating the discussion about the factors that influence the distinct local preferences (RQ1).

Complementing the observations directly drawn from the current study, other aspects such as the academic and professional contexts were deemed as relevant in order to understand the ranking of preferred roles (RQ2). In fact, it seems that the impact of these dimensions can be identified as:

1. **Academic Context**: the IEM curricula of the university plays a key role in influencing the preferred roles towards the content of the subjects taught, in particular, in the locations that have a significant difference of percentage between the first preferred role and the second and third. This is in line with previous research which already underlined universities' responsibility in influencing students' career decisions (Lichtenstein et al, 2009).
2. **Professional Context:** the Alumni experiences reveal that the professional transition of the students of the selected universities are most likely to be influenced by the employment opportunities along the student's path, such as business-based dissertations and internships in specific areas. With this observation, the studied universities seem to influence the professional transition towards the content of their curricula, reinforcing the preference related to roles suited for these areas.

On a European perspective, the distribution of preferred roles varies between the studied locations, showing a non-uniform distribution that can be influenced by university-based factors such as the curricula or employment opportunities. Therefore, it seems like there is no generic role preference within the European scenario, which highlights that it is important that a student takes time to select a university aligned with their personal career ambitions or, as an alternative, postpone the decision-making process to select their career ambitions influenced by the selected university's characteristics and dominant roles. Furthermore, based on those results, it is important for higher education to realize that all the roles are required on the labour market. If a university is focussing on giving insights to their students on one particular role, it can have damaging effects on the students themselves. In fact, their preferences can change from what they were when they started their study journey to when they start their career.

5.1 Limitations of the Study

In this exploratory study, we relied on the local association for the distribution of the survey. Consequently, we were bound to the local communication channels, which were mainly online due to the COVID-19 and encountered difficulties in estimating the reach of the survey inside each university. The findings should be interpreted within these boundaries.

Also, we noted a limited amount of personal information shared by the surveyed. This resulted in collected data that are mostly based on global aspects such as the university and degree of studies. Future research including personal data may benefit the overall analysis.

Furthermore, the interviews should be conducted on a bigger sample of participants as it is highly likely that the responses are influenced by one's personal experiences.

5.2 Further Research

Further research is recommended to take into account additional information related with personal characteristics (age and gender) and preferences, as well as professional experience (extracurricular and research). In fact, a new study aiming to gain a deeper understanding of the factors influencing the role preferences may be conducted by ESTIEM. With this broader scope, the PREFER Explore test can also be applied to more universities in more countries, targeting according to specific criteria such as their curricula classification.

For a next step, providing the opportunity to apply the second test developed based on the PREFER model, in this case, the specific PREFER Match survey for the dominant preferred role, enabling a deeper analysis on the competency level, complementing this first research conducted on a global dimension.

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Game-based learning in a Production Engineering course in Brazil

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Abstract

Production Management courses are key points in Production Engineering programs. Teaching concepts of Lean Manufacturing and Theory of Constraints (TOC) is an arduous task, since it involves the need to establish several important fundamentals. Traditional classes based on blackboard and speech tend to bring monotony and lack of interest to students, reducing their retention of content. On the other hand, there are active teaching methodologies that allow these concepts to be better worked and fixed. Among these methodologies is the Game-Based Learning (GBL). Based on the use of games for educational purposes, GBL allows simulate some scenarios and teach concepts, while take decisions. For about ten years, Production Management (III and IV) classes at the researched institution have been held with the support of different games: the "Beer Game" and the "Lean Board Game", in physical format and "Goldratt Simulator", a virtual simulator. Although the teacher of the subjects understands the importance of using games to complement the classes and understanding the concepts covered, this application had not been the target of previous researches. In 2020, a research focused on the use of games in Production Engineering courses resulted in the implementation of steps and methods in order to analyse the gains from the implementation of the games in the subjects. The research model adopted divides students into a control group and a test group, with the application of learning and perception assessments by the participants.

Keywords: Game-based learning; Production Engineering; Active Methodologies; Games.

1 Introduction

Brazilian education has undergone significant changes stimulated, mainly, by the implementation of the new National Curriculum Guidelines, which encourage the use of active methodologies in the teaching of engineering.

The updates proposed in the document seek to reduce the gap between university education and the needs of the market. According to Lázaro et al. (2018), active methodologies turn the student the most responsible for their learning, transforming it into the centerpiece of their training, which contributes to the development of significant competences: autonomy in learning, time management, prioritization of actions, decision making, among others.

Currently, dozens of types of active methodologies can be listed, among them: Project Based Learning, Problem Based Learning, Flipped Classroom, Team-Based Learning (TBL), Challenge Based Learning, Gamification, Game Based Learning (GBL).

Allied to this are the subjects of great value in academic education and which can be benefit from active methods of teaching and learning. In Production Engineering courses, Production Management subjects are perhaps the most important, presenting different theories and methods of management, which can be better understood through simulations and practical studies.

As it is not always possible to involve students in practical environments, through internships and partnerships with other institutions, teachers can use games and simulators, to improve the classes. This is because, according to Herrera et al. (2019), the complementation of traditional classes (Lecture) with GBL results in better learning, with greater student engagement, once that games stimulate learning, while making moments of interaction, simulation and reflection into relaxed and motivating experiences (Kishimoto, 2004; Machado et al., 1990; McDowell et al., 2006).

In addition to the motivational issue, games allow greater absorption of the content worked on, since they create valuable experiences and bring error as a source of learning (De Sousa & Salgado, 2015; Prado, 2018).

An example of this application is found in the Production Engineering course at a renowned Brazilian educational institution. The case in question, is aimed at Production Management III and IV, subjects whose main contents are: production planning, programming and control and the theory of restrictions and lean manufacturing, respectively,

For about 10 years, these subjects have been carried out with the support of different games: the "Beer Game" and the "Lean Board Game", in physical format and "Goldratt Simulator", a virtual simulator. But, although the teacher of the subjects understands the importance of using games to complement the class and understand the concepts covered, this application had not been the subject of research until the present moment.

However, in 2020, a research focused on the use of games in the Teaching of Production Engineering was initiated. With the research, there was a need to establish appropriate steps and methods capable of analyzing the gains from the implementation of the games in the course. Based on this research, a work model was proposed, which is presented in this article and is the main objective of this work.

2 Literature Review

The active methodologies are any educational approach in which students actively participate in the learning process, becoming the centerpiece of the process and the main responsible for their learning (Lázaro et al., 2018). They encourage debate and practice, as well as the revision of knowledge through explanation with other students, which, according to William Glasser's learning pyramid, results in higher levels of learning.

Measuring these learning gains has been a challenge for researchers who end up creating their own tools based on pedagogical theories and assessment models. Among the literature related to the use of games in the Teaching of Production Engineering, different theories, methodologies and tools are found, such as:

- **Bloom's taxonomy:** aims to assist in the identification and declaration of objectives related to cognitive development (Ferraz & Belhot, 2010). After updates, Bloom's Taxonomy is synthesized by the following categories: remember (knowledge), understand (understanding), apply (application), analyze (analysis), synthesize (synthesis) and create (evaluation).
- **Logic of input-process-outcome:** Fully aligned with the idea of transformation process, the logic of input, process and outcome is an excellent tool for the development, improvement and evaluation of games (Hense et al., 2009). Through this logic, developers and instructors are able to identify needs, objectives and plan the actions necessary for learning to be effective.
- **Keller Model or ARCS (Attention, Relevance, Confidence, Satisfaction) Model:** is a motivational design model that focus on elements that intended to ensure that the subjects worked are relevant and attractive and assist in the development of confidence and satisfaction of those involved (Kaneko et al, 2015).
- **Kirkpatrick model:** developed with the aim of analyzing and evaluating the results of training and education programs. It takes into account any style of training, both informal and formal, to determine the effectiveness of training based on four-level criteria: comprising reaction, learning, behaviour and results. The model must be implemented before, during and after training. The assessment must start at level one, progressing in the order of the levels (Smidt et al (2009).
- **Flow Theory:** developed by Mihaly Csikszentmihalyi in the 60s (Almeida & Budazy, 2019), the theory argues that there is a state (flow) in which a person is completely absorbed by a pleasant activity. In this state, in which the person does not even notice the time that passes, he is able to produce and achieve his best results, because mind and body are completely integrated and immersed in the moment. According to Yen and Lin (2020), the concept of flow has been widely applied to the context of sports, work, shopping, games, website use and computer use. In the context of game-based learning, the results of previous studies indicate that games help to place students in psychological states that increase their involvement in learning activities and focus on the tasks in question. According to Buil et al. (2018), Csikszentmihalyi's findings revealed that flow is achieved through a combination of skill and challenge.

In addition to these, other more specific approaches are found, such as: the SECI Model (Allal-Chérif et al., 2016), focused on knowledge management, "The Nine Gagne Events" (Mavromihales, 2019), which are steps towards a good instructional application, in line with mental learning conditions.

The approaches presented require planning, and must be supported by assessment tools, such as: questionnaires, forms and learning assessments. However, before establishing such tools, it is important to establish the group (s) that will be analyzed. The research can be carried out using:

- **Focus group:** These are useful groups for investigating complex behaviors that allow the researcher to interact with the participants. According to Krueger and Casey (2014 apud Almeida & Budazy, 2019), three elements are fundamental for the definition of a focus group: (i) number of participants: it must be between 2 (two) and 12 (twelve), at most; (ii) time limit: must be limited to two hours or less; and (iii) diversity: it must include people with characteristics common to the studied topic, with equal distribution of characteristics. Due to their quantitative limitations and strong interaction with the researcher, focus groups are used for qualitative analysis.
- **Control group and experimental group:** These are groups in which one of them is put in contact with the proposed experiment / treatment (experimental group) while the other is not undergoing intervention (control group). Experiments of this type are seen as controlled experiments, in which it is possible to test a hypothesis. For these groups, it is common to use post-experiment tests, comparing the results with each other.
- **Individual or several groups:** If it is impossible to carry out balanced and independent segmentations, it is possible to choose to carry out individual experiments and unify the applications by analyzing all the data in a grouped manner. When the control group is not established, it is common to perform pre- and post-tests, so that they can be analyzed and compared.

Regardless of the way established for the experiment, it is important that the data obtained are analyzed statistically, in order to verify the coherence of the answers (Cronbach's alpha), the interdependence of the variables (t tests) and the significance of the results (p-value).

Knowing what you want to measure is the first step in defining the experiment to be applied, as well as the assessment tools to be used. The main forms of evaluation the use of games are:

- **Perception assessments:** they help in the validation of games regarding their attractions (usability, entertainment) and attributes (learning potential). It is common for perception assessments to be based on flow theory, validating the immersion and engagement provided by the game (Khan & Pearce, 2015).
- **Self-assessments:** commonly performed in the pre and post-experiment model, self-assessments seek to identify changes in knowledge and behavior based on the participant's point of view. They are common assessments to be applied when behavior tends to change based on awareness, as when the subject is sustainability (Bascoul et al., 2013; Chappin et al., 2017; Cuesta & Nakano, 2017)
- **Learning assessments:** analyze the effectiveness of what has been learned. The tests can be performed from multiple choice questions, TRUE/FALSE and/or open/closed questions. The style of the questions is what will determine the level of evaluation, being able to stay only in the lower parts of Bloom's taxonomy (multiple choice questions) or transpose to the highest ones.

The assessments described can occur at different times, before (pre) and/or after (post) the experiment. However, according to All et al. (2017), pre-tests (assessments of learning before the experiment is carried out) do not seem to be an interesting tool, since they indicate what will be evaluated and, in this way, induce an intensification of studies in a more focused way.

3 Methodology

From a bibliographic research on the methods of validating the use of games in Production Engineering and related areas, it was possible to identify theories and assessment tools, which were analyzed, resulting in the proposal of a model for the application and evaluation of the use of games that could serve as a starting point for similar research.

In this way, this study is characterized as applied research, with a qualitative approach, with exploratory objectives, carried out through data collection through bibliographic and documentary research (Silva, 2001). Through the experiment it is also classified as a quantitative research, carried out to validate, not only the game, but also the proposed evaluation methodology.

A systematic research was applied, using in the following terms by Title, Summary and Keywords: ("educational game" OR "serious game" OR "game-based learning") AND ("production engineering" OR "industrial engineering" OR "manufacturing engineering" OR business OR logistic OR administration OR "supply chain" OR manufacture)

This research returned 419 published articles, in English and in Journal, which were evaluated, finding 15 significant experiments and diverse materials that reinforce the bibliographic review.

From these results it was possible to propose a structured model for the application and evaluation of the use of games, which has been used in the Production Management IV subject.

4 Development

Following theories, group formation and assessment tools, the proposed and developed model was divided into five stages:

1. **Definition of objectives (Figure 1):** From the subjects' teaching plan, the objectives of the experiments are identified through Bloom's Taxonomy;
2. **Design of the experiment (Figure 2):** Using the input - process - outcome model, the necessary components for the experiment are identified, the questionnaires elaborated and the whole process of application of the game is defined;
3. **Development of monitoring and validation models:** Based on the theories presented and the experiments observed, this study suggests to apply:
    a. **a previous participant's characterization questionnaire (Figure 3):** in order to guarantee equivalence between the control and the experimental groups. This questionnaire should have characteristics such as: gender, age, level of previous knowledge about what will be addressed and the tool used. Following the defended by All et al. (2017), this first questionnaire should not ask conceptual questions;
    b. **a perception questionnaire (Figure 4):** the perception / validation questionnaire of the game must be applied at the end of the experiment in order to identify the level of flow;
    c. **a post-test (Figure 5):** to validate the learning, a TRUE/FALSE test should be applied to work on concepts, another multiple choice or even dissertative approach may compose the evaluation;
    d. **a self-assessment questionnaire (Figure 6):** the self-assessment questionnaire should serve as a immediate feedback, based on statements that respond to the conceptual part of the post-test.
4. **Application of the activity and tools:** at this point, the classes plan is already adequate to carry out the different activities for the two groups.
5. **Analysis of results:** using statistical analysis, the following hypotheses are tested:
    a. H1: the validation model is congruent (the results obtained between the tools are correlated)
    b. H2: the use of the game allows for improvement in learning (evaluations of the experimental group are significantly better than those of the control group):

5 Results

To date, applied research has advanced the first three stages, being at the stage of applying the proposed model. Thus, the contribution of this study is the proposal and presentation of the models used by the three initial stages, detailed in the following items.

5.1 Definition of objectives

From the teaching plans of the subjects and Bloom's Taxonomy it is possible to identify the objectives of the game to be used and thus choose the most appropriate game / simulator. Thus, the first step proposes the analysis of the objectives of the subject according to Bloom's taxonomy for the definition of the best game/simulator to be used.

Production Management III – Objective: Analyse and create production planning and scheduling systems in companies

Production Management IV - Objective: Understand the functioning and the importance of integrated management systems, with special attention to the production area.

Cognitive domain categories	Production Management III	Production Management IV
1. Remember (knowledge)		
2. Understand (understanding)		X
3. Apply (application)		
4. Analyze (analysis)	X	
5. Synthesize (synthesis)	X	
6. Create (evaluation)		

Figure 1. Proposed objectives and their analyses by Bloom's Taxonomy.

Although Bloom's Taxonomy argues that the higher degrees must be preceded by the lower levels so that they can be well worked and absorbed, it is noted that, in this experiment, the subject of Production Management III brings comprehensive concepts, already worked by other subjects (Production Management I and II) and, therefore, there is a greater advance in the categories. In the sequence, the subject of Production Administration IV presents more defined concepts which translates into a need to add new knowledge and invest in its understanding. The proposed experiment, however, aims not only to understand these concepts, but also to apply them, since it allows them to be executed through simulation.

5.2 Design of the experiment

The input - process - outcome model helps to plan the needs and actions to develop the experiment.

INPUTS	PROCESS	OUTCOMES
Students: Age, gender, prior knowledge, motivations and expectations **Game / simulator:** Content and usability **Teacher:** Knowledge, motivation, expectation and preparation	**Definition and division of working groups** (experimental and control) **Experiment application** (in line with the ARCS model) **Game feedback** (decision results) **User feedback** (discussions and responses to questionnaires)	**Acceptance:** results of perception assessments **Learning:** results of post-test evaluations **Validation:** results of self-assessments and post-test assessments

Figure 2. Design of the experiment by the input - process - outcome model

5.3 Monitoring and validation models

Different tools were developed, based on the literature, as a way of proposing a consistent model, capable of obtaining qualitative and quantitative information for the initialization and analysis of the experiment.

5.2.1 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)[1]?

( ) 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, analyze 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 enroll 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

[1] Main concept subject to be worked on in the experiment

Figure 3. Specific participant's characterization questionnaire

Such 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 organized.

5.3.1 Perception questionnaire

Perception analyzes 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 4. A generic developed perception questionnaire

5.3.2 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 realization of conceptual questions that could be analyzed in a practical 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 several restrictions that make it difficult to reach their goal
2. The theory of constraints (TOC) states that great locations result in great globals
3. Inactive capacity constrained resources (CCR) block the goal from being achieved
4. Bottlenecks impede demands from being met
5. Bottlenecks and CCRs are synonymous
6. The buffer is the stock of materials in process that must exist throughout the production lines
7. The rope is the production sequencing that is based on the drum
8. The CCRs is the drum and it is from there that production must be planned
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 earned throughout the system

Figure 5. The post-test with specific questions about Theory of Constraints

5.3.3 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 analyze their own level of understanding.

Analyze 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 one or a few restrictions that make it difficult to reach their goal.

2. The theory of constraints (TOC) states that great locations do not necessarily result in great globals

3. Inactive Capacity Constrained Resources (CCR) will only block the goal from being reached if the adopted strategies turn it into a bottleneck (active CCR)

4. Bottlenecks impede demands from being met

5. Bottlenecks and CCRs are NOT synonymous. The CCR will only be a bottleneck when its capacity is or becomes less than necessary

6. The buffer is the stock of materials in process that must exist to ensure that the CCR (active or inactive) does not stop and for ensure that its production will be readily assembled and shipped

7. The rope is the production sequencing that is based on the drum

8. The CCR is the drum and it is from there that production must be planned

9. An hour lost on a NO bottleneck resource is NOT an hour lost on the entire system, but an hour lost on a bottleneck resource is an hour lost on the entire system.

10. An hour saved on a resource does NOT bottleneck it is NOT an hour earned across the system.

Figure 6. The self-assessment with specific affirmatives about Theory of Constraints

6 Conclusion

As a result of the Covid-19 pandemic, the classes schedules were changed, what postponed the beginning of the activities and therefore the experiment. Thus, it was not possible to finish the study and to present all the intended analyses on time.

However, it is clear that the proposal of a model of implementation and evaluation of the use of games for educational purposes becomes relevant, once there is the need to prove the effectiveness of tools and methodologies that complement the teaching-learning process.

This study presents a methodology that suggests the division of control and experimental groups in order to analyze the possible gains from the use of games and simulators. In order to carry out such an analysis, it is proposed to apply perception, learning and self-assessment questionnaires. Such questionnaires were designed to be simple to be answered and analyzed, based on different models found in the literature.

With the application of the following two steps, it will be possible to perform statistical analyses to verify the validity of the proposed model and the effectiveness of the use of the specific games (Beer Game and Lean Board Game) and simulator (Goldratt Simulator).

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The use of games in a graduation course in an engineering faculty

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Abstract

The quality of education did not accompany the Brazilian effort to increase the number of students in higher education, contributing to this the small number of practical classes and interdisciplinarity.

The publication in 2019 of the new National Curriculum Guidelines changed the focus of content-based teaching to teaching focused on skills development. Game-Based Learning (GBL) generates greater engagement, motivates action, promotes learning and problem solving in a creative way and reduces resistance in the face of complex themes.

In the researched institution it was observed that since 1999 there are experiences with the development and use of games. Among the games found there are simulations and games in digital and board format. The main games used are the Beer Distribution Game and the Lean Board Game, in board format, and the games Bomburguer, Lemonade Stand Game, Virtual Market, Strategy and Sustainability Simulation, Strategy Simulation, Production Planning Simulation, Simulated Model in PROMODEL, Kanban Game and Distribution Game. The games found focus on teaching production management and logistics, strategy and sustainability. Some of the games used focus more on the technical aspects of a specific concept, such as the Lean Board Game, Kanban Game and Goldratt Simulator games.

Production Engineering courses has many interfaces with other areas and there are possibilities to expand the use of games in that institution, contributing to the improvement of teaching and expanding the use of active methodologies in its courses. The research is a case study and was carried out in the following stages: the first sought to find the games used in a course, then the games used in the area and, finally, compared the curriculum with the games found in the area. It is concluded that there is space to expand the use of games and, consequently, the adoption of active methodologies in the analyzed course.

Keywords: Serious Games; Game-based learning; Production Engineering Course.

1 Introduction

The professional trained in Production Engineering must have skills that enable him not only to make physical-technological changes, but also to conduct economic and social changes in the reality that surrounds him (Nakao, 2018). In this way, it acts to design, improve, and implement sustainable production systems for goods and services. For this, it must combine resources of different natures, such as information, equipment, materials, people and energy (Batalha, 2008). It is concluded, therefore, that the interdisciplinary nature is intrinsic to the activity of the Production Engineer.

However, there are obstacles for the training of engineers able to face the challenges faced by the society of the 21st century. Among the biggest bottlenecks present in the current formation of the Production Engineer, stand out, among others, the low volume of practical classes and the challenges of interdisciplinarity (Velho, Costa & Goulart, 2019). Corroborating this, Pavanello, Germano & Freitas-Lemes (2017) affirm: "despite the interdisciplinarity in engineering courses being characterized as a crucial step for the formation of more qualified and prepared professionals for the current job market, actions with this focus they are still few and isolated".

Parallel to this, engineering education presents itself as a promising field for the application of the so-called active teaching methodologies. According to Barbosa & Moura (2014), what differentiates an active learning environment from another that is passive is the "active attitude of intelligence", as opposed to the "passive attitude of intelligence". Therefore, in an active perspective, the student must make use of his mental functions, such as observing, reflecting, thinking, combining, understanding, reasoning, among others.

Going further, several authors point to the effectiveness of active learning compared to traditional methods. Through active methodologies, students feel more able to apply the knowledge developed in practical situations, learn to express themselves better and improve their interpersonal skills when interacting with classmates. With the use of active methodologies, students can better understand the convergence between different disciplines (dos Santos, 2017), a fact that encourages an interdisciplinary view during the learning process. In addition, placing themselves in an autonomous posture, they acquire a taste for problem solving, while experiencing situations that demand decision-making on their own (Ribeiro, 2005; Silberman, 1996). This is also stated by Fontes & Gontijo (2020), who, in addition, adds encouragement to the critical formation of the individual as an important advantage of using active methodologies.

So, if engineering is a promising field for the implementation of methodologies capable of meeting demands in relation to practical classes and interdisciplinarity, why does your teaching have deficits precisely in these aspects?

In view of the exposed incongruence, an important reflection arises: "how can universities adapt their teaching methods so that the current challenges in engineering education are overcome?"

An alternative to this problem may be to encourage the "active attitude of intelligence" through active teaching methodologies. Among them, the application of games with didactic purposes stands out, because according to Gunther, Kiesling & Stummer (2011), they have a recognized potential to supply several learning deficiencies, such as the student's lack of motivation. Nevertheless, according to Da Matta (2020), keeping in mind the different options of providing practical experiences, the use of simulators is emphasized, among them, games with educational purposes, which constitute a possible alternative to make pedagogical practices more active, dynamic and fun. Combining game-based learning with the use of adequate resources, good theoretical references and an interdisciplinary approach, the use of games is capable of providing effective learning that meets the requirements of modern education (Greipl, Moeller & Ninaus, 2020).

Furthermore, it is pertinent to highlight the profile of the engineering faculty in which this research was carried out. With regard to geographic location, the research institution is a public university located in the state of São Paulo, Brazil. According to the information available on the college's website, it was founded in 1967 and appears on the list of the 400 best universities in the world, in a ranking of eight thousand institutions. Locally, it is present in the ranking of the Top 10 best universities in Latin America, according to Times Higher Education (THE) and the Superior Council for Scientific Investigations (CSIC), as can be seen in its 2020 and 2021 rankings, respectively. Therefore, the chosen university, despite being classified as a relatively young university, is in a position of great relevance with regard to the training of Brazilian engineers. Due to these characteristics, the choice of the faculty in which this research was carried out is justified.

That said, this work set out to investigate "The use of games in a graduation course in an engineering faculty", with the main objective of identifying the types of games used, through the application of a questionnaire with the professors of Production Engineering courses at said institution. Reaching these objectives, the present work can support a possible proposal to improve the curriculum, to be sent to the council of the mentioned course. However, it is important to highlight that the results of this research refer to the context of the investigated faculty, and that the use of games in teaching, despite being a promising practice, must be calibrated to the specifics of each reality. Therefore, the authors hope that this article can serve as an inspiration for new research and methodologies to be considered in the teaching of engineering, not only at this university, but also in other institutions in Brazil and around the world.

2 Literature Review

In contrast to traditional classes (lecture), characterized by expository teaching, we have active methodologies. To explain the basic precepts that guide active teaching methodologies, it is possible to recall the Chinese proverb uttered by the thinker Confucius, even before Christ: "What I hear, I forget; what I see, I remember;

what I do, I understand”. Going further, it is prudent not to forget the importance of not only doing but feeling what is being done. This is because the feeling associated with an experience can be a preponderant factor for the fixation of knowledge. In this way, active methodologies, by stimulating high-level mental tasks, such as analysis, synthesis and evaluation, fit perfectly with the demands present in the current teaching of engineering (Silberman, 1996; Fontes & Gontijo, 2020).

2.1 Problem-based Learning

Problem-based learning consists of using contextualized problem situations, real or not, to guide the learning process. In this method, the student ceases to be a passive receiver and becomes the center of the process, while the professor acts as an advisor for the working groups. Although its application varies according to the level and type of education, as well as with the area of knowledge and with the learning objectives, in general terms, the problem-based learning involves the following steps: Beginning; Generation of Ideas; Analyze; Elaboration of Questions; Learning Objective; Synthesis and Evaluation; Study and Presentation (Barbosa & Moura, 2014).

2.2 Project-based Learning

In summary, the purpose of project-based learning is to use projects as a pedagogical resource. Projects are carried out based on the problems, needs, opportunities or interests of individuals. Thus, students must make efforts with a determined time and scope in order to achieve a final goal. The characteristics of project-based learning are of great relevance for engineering training. As a teaching method, the project for educational purposes must have four essential phases: Intention; Planning; Execution; Judgment (Barbosa & Moura, 2014; Venturini & Silva, 2018).

2.3 Team-based Learning

This method seeks to improve not only the results of the learning process, but also to develop collaborative work skills. For this, a structure that involves management of learning teams, preparation and application tasks, constant feedback and evaluation among colleagues is used. The implementation of team-based learning is structured in modules that involve prior preparation and application, both in class and out of class, by the student. After the main concepts are discussed, the teams must solve application tasks, usually of the “problem solving” type, which become increasingly complex and stimulating (Oliveira, Araújo & Veit, 2016).

2.4 Flipped Classroom

This strategy, also known as "inverted classroom", has been gaining more and more prominence, this because it aims to optimize the time in the classrooms. For this, the professor can create a video lecture, screencast or vodcasts that teach students the concept of the subject. Thus, the content can be consumed by students in advance, allowing more free time in the classroom for more engaging and collaborative activities between students and professors (Milman, 2012).

2.5 Gamification

The Gamification is based on the principle that, in general, people do not feel as capable in real life as in games. In real life, when faced with obstacles, people tend to feel depressed, overwhelmed and frustrated, feelings that are not present in the gaming environments. Thus, gamification consists of implementing, in everyday situations and in productive activities, elements present in games, so that people feel more stimulated, influenced and motivated. To achieve this purpose, this method uses a series of design, process and system principles to direct the behavior of individuals, groups and communities (Huang & Soman, 2013).

2.6 Game-based learning

In view of the countless methodologies considered active, the use of games presents itself as a viable alternative in relation to the reality of most educational institutions. Thus, it is important to highlight that games with a didactic purpose can be applied from the perspective of different approaches, for the development of different skills. Among them, we can highlight those related to production operations (Denami, 2018). Similarly, they are used for strategic simulations within countless contexts, especially for the improvement of skills related to: business, management and professionalism (Zyda, 2005).

According to Cheek et al. (2015), games enable the creation of safe and responsive environments, allowing users to model, test and change new scenarios, according to their application needs. Another important characteristic is that this learning tool provides the systemic experience of the largest number of human and organizational skills possible, since students must seek to mobilize all the knowledge previously acquired in order to obtain a good performance during the game. In addition, games with a cooperative purpose function as an instrument of articulation and promote the educational process, being able to bring motivation and a feeling of inclusion to students, stimulating creativity, spontaneity and valuing the effort of others, which allows for growth synergy of all participants (Amaral, 2009; Greipl, Moeller & Ninaus, 2020).

Nevertheless, according to Connoly et al. (2012), the use of games is promising in relation to the stimulation of a wide range of cognitive skills, such as: concentration, attention and memory. Regarding behavioral skills, Fleming et al. (2017) highlights the development of characteristics essential to managers, to be highlighted: empathy, engagement and effectiveness. Finally, when it comes to games with a focus on decision making, skills such as holistic vision and systemic thinking are developed, as students must consider several variables when making their decisions (Whalen et al, 2018). It should also be noted that all the skills scored are recognized as crucial to excellence in resource management., which is very important to Production Engineers.

2.7 Other active methodologies

In addition to the methodologies presented, there are countless others that could be highlighted, this because teaching is a dynamic area in which, increasingly, new ways of meeting the needs of the teaching and learning process have been sought. Among these methodologies, we highlight: Challenge Based Learning, Peer Instruction, Just-in-Time Teaching, Simulations, Inquiry-based Learning, Think-Pair-Share, among others. Therefore, it is important to make it clear that one of the limitations of this work is characterized precisely by the impossibility of raising all available active methodologies. In addition, it is worth mentioning that many of these methodologies are analogous and / or complement each other, and the final aim is always the same: to stimulate the active attitude of intelligence. For this research, we sought to highlight different methodologies that are not redundant with each other, that is, which are not based entirely on the same principles and concepts of application.

3 Method

To conduct this research, which aims to "identify the types of games used, based on an opinion survey with the professors of that institution regarding the use of games", the form tool provided by Google, known as "Google Forms". The created form consisted of 3 sections and 6 questions, 5 of which are mandatory. After its creation, it was sent to the professors of the Production Engineering departments, of three campuses, of the referred institution.

The first section was dedicated to the use of educational methodologies and games in the teaching of Production Engineering (PE). The purpose of this section was to identify the degree of knowledge and use, on the part of teachers, regarding active teaching methodologies. For this, the following question was elaborated: "For the teaching methodologies below, check the most appropriate alternative for your case", In the question, 7 teaching methodologies were listed, along with options that should be checked by the teachers.

The second section, called "Game-Based Learning", had the purpose: to identify the teachers' opinion regarding the application of games in the classroom. Thus, the following question was elaborated: "Regarding the use of games in the classroom, you:" with 5 answer options, so that the respondents would say if they agree with the use of games and if they use them to teach classes.

With regard to the last section, "games for teaching PE", the objective was to survey the games already used by teachers at the institution. Thus, the following question was presented: "Of the games below, choose the most appropriate alternative for your case", followed by 14 game options (of the most varied types) directly or indirectly related to production engineering, so that, the teachers pointed out if they knew them and if they used them. In addition, the question was also asked: "What other game (s) do you use in your classes?", With a field for the answer to be typed. Finally, it was asked: “In your opinion, what is the most appropriate game format to support the teaching process?”, So that they could choose between “physical / non-digital”, “virtual / digital” or “both are equally important ”. The results of this section are shown throughout item 4.3.

Regarding the structure of the form, the teachers who, in the second section, answered that they use games, were directed to answer the questions in the third, and last, section, while those who answered that did not use games were directed to the conclusion and sending the questionnaire. The links to the involved games are listed in table 1.

Table 1. Links of the games involved in the survey.

Game	Link
Automania	https://boardgamegeek.com/boardgame/176544/automania
Automobile	https://boardgamegeek.com/boardgame/39351/automobile
Beer Game	https://beergame.masystem.se/
Bomburguer	http://bomburguer.net/Home.aspx
Distribution Game	https://web.lemoyne.edu/~wright/trucks.htm
Goldratt Simulator	https://www.yumpu.com/pt/document/view/62445859/goldratt-simulator
Healthy Heart Hospital	https://boardgamegeek.com/boardgame/186721/healthy-heart-hospital
Imagine	https://boardgamegeek.com/boardgame/191894/imagine
In the Loop	https://intheloopgame.com/
Kanban Game	https://boardgamegeek.com/boardgame/109276/kanban-drivers-edition
Lean Board Game	http://leanboardgame.com/
Lemonade Stand Game	https://boardgamegeek.com/boardgame/173560/lemonade-stand-game
Mobility Game	http://civitas.eu/cs/tool-inventory/mobility-serious-game
Oh My Goods!	https://boardgamegeek.com/boardgame/183840/oh-my-goods
Platform Kahoot	https://kahoot.com/
Production Dice Game	https://www.vlerick.com/en/research-and-faculty/knowledge-items/knowledge/the-production-dice-game
Sustainability	https://boardgamegeek.com/boardgame/30490/sustainability
The Manhattan Project	https://boardgamegeek.com/boardgame/177249/manhattan-project-chain-reaction
Virtual Market	http://mercadovirtualfeb.com.br/

Note: only games with digital format and / or with a promotion website are listed. The games not included in this list are found only in physical format and / or do not have a publicity website.

4 Results

The questionnaire was sent to 35 teachers from 3 different campuses. Of the total, 22 responded and 13 did not. Among the respondents, 9 use games and, therefore, were sent to answer all questions on the form (sections 1 to 3), while 13 do not use them, limiting themselves to answering only the questions in sections 1 and 2.

4.1 Results of the first section of the form

The first section aimed to identify the degree of knowledge about active teaching methodologies, in relation to the traditional method (“lecture”) of expository classes. For this, the following question was posed: “For the teaching methodologies below, check the most appropriate alternative for your case". The result is shown in figure 1.

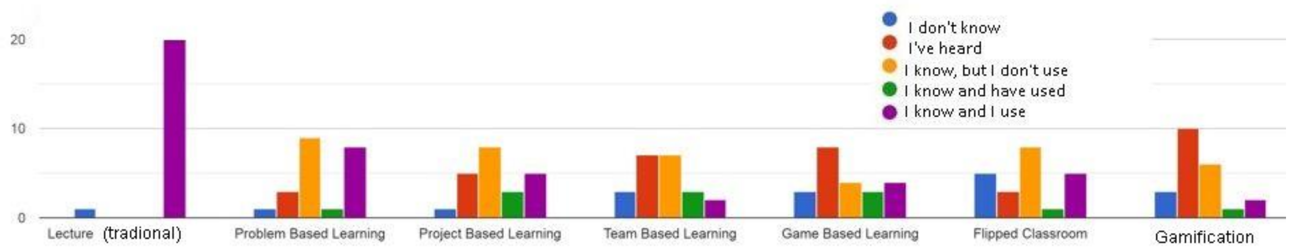

Figure 1. Visual representation of the responses in the first section.

Analysis: it is noted that most teachers make use of traditional classes ("lecture") and that the level of application of teachers in relation to other methodologies is still low, with higher levels for the use of "Problem Based Learning" and "Project Based Learning".

4.2 Results of the second section of the form

The second section aimed to identify the teachers' opinion regarding the application of games in the classroom. Thus, the following question was elaborated: "With regard to the use of games in the classroom, you: ". The result is shown in figure 2.

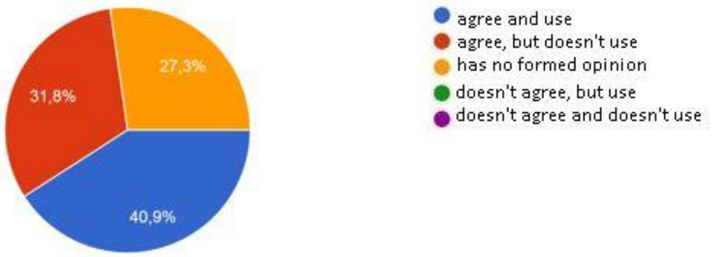

Figure 2. Visual representation referring to the answers in section 2

Analysis: in total, 16 (72.7%) teachers agree with the use of games, 6 (27.3%) have no formed opinion and none (0%) disagrees with its application. An interesting fact is that, some of the teachers who claim to use games for teaching, are unaware of the concepts of "Game Based Learning".

4.3 Results of the third section of the form

Finally, the objective of the last section was to survey the games already used by the institution's teachers. Thus, three questions were asked.

First question: "From the following games, choose the most suitable alternative for you".

In this case, of the 14 games presented, 2 were not known by the teachers: the "Healthy Heart Hospital" and the "Oh My Goods", while the best known were the "Lean Board Game" (4 citations) and the " Beer Game "(3 quotes). Regarding the games they use in their classes, there were 4 games mentioned: "Sustainability", "Virtual Market", "Kanban" and "Bomburguer". While some mention having already used: "The Manhattan Project: Chain Reaction", "Lean Board Game", "Kanban" and "Beer Game".

Second question: "What other game (s) do you use in your classes?".

In this field, teachers were free to present other games they use in the classroom. As a result, different titles were cited, such as: "Distribution Game", "Lemonade Stand Game", "Goldratt Simulator", "Production Dice Game", "SDE Strategy Game (LDP)", "Pin Board", "Platform Kahoot", "Lean Factory", "Hunt the Vampire" and

"Imagine". Among these games, the most cited were "Dice Games" and "Goldratt Simulator" (2 quotes). All the others were mentioned only once.

Third question: "In your opinion, what is the most suitable game format to support the teaching process?"

As a last question, we sought to identify the teachers' preferences, considering that the game formats have peculiarities (degree of socialization, immediate feedback, agility to understand the rules). It was noted that the majority of teachers who use games believe that both formats are important, followed by the preference for virtual / digital games.

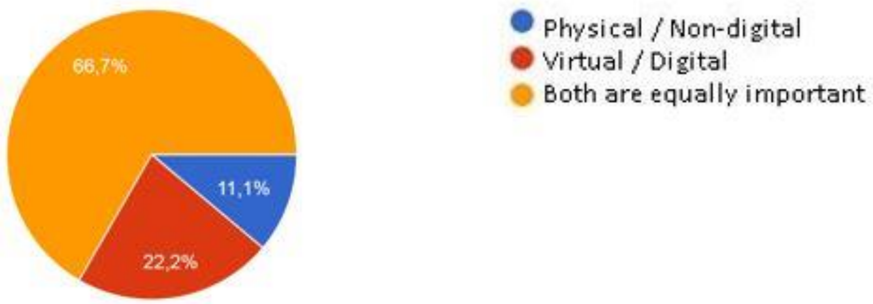

Figure 3. Visual representation regarding the answers to the third question in section 3.

Analysis: it was noted that the majority of professors who use games believe that both formats are important, followed by the preference for virtual / digital games.

5 Conclusion

According to the consensus perceived in the bibliographic works, it is known that the use of games as a teaching method is a promising practice, precisely because of its ability to work on two of the biggest bottlenecks present in the current training of engineers: the lack of practical classes and the challenges of interdisciplinarity. With regard to the university where the research was carried out, a curriculum structure more aligned with active teaching methodologies was to be expected, due to its youthfulness.

In relation to the objectives that justify this research, it was possible to identify that the majority opinion of professors who teach at that institution, in relation to the use of games, is favorable. Illustratively, 72.6% of the professors agree with the use of games in teaching, while only 27.3% have no formed opinion on the subject, as shown in graph 2. However, this favorable opinion does not translate into the application practice of this method, since only 9, among the 22 respondents, use or have used games to teach their students.

In addition, 13 games currently used by the university's Production Engineering professors were identified. In general, it was found that professors who apply games tend to use more than one game in their classes. However, many of the games traditionally used in teaching Production Engineering are not known to most professors, such as the "Beer Game". This reveals that, in fact, this theme is not yet widely spread among the institution's professors, and this is not an exclusive feature of this university, as can be seen through the work of Barbosa & Moura (2014).

Another important point is the slight preference for virtual games, which may be the result of the current pandemic (by Coronavirus) scenario that still plagues the country, making it impossible to apply games in person.

Among the biggest difficulties faced to carry out this research, it points out the impossibility of raising all the available active methodologies, this because, in the case of an extremely dynamic field, there are numerous methods being created every day (although most of them are redundant). In addition, the reported results refer to the specific context in which the faculty studied is inserted. Thus, as recommendations for future research, the authors recommend that its scope be expanded, that is, that new methodologies be included. It is also warned that the results of the use of games may vary according to the peculiarities of each situation and, therefore, their application must be calibrated to the specifics of each reality.

Ultimately, it was realized the existence of a promising future for games, allowing them to gain more and more space in classrooms. Specifically, in relation to the target university of this research, the positive position of the professors regarding the use of active methodologies, especially the use of game-based learning, was clear. Despite this, there is still considerable scope for other teaching methods, in addition to the traditional one, to be put into practice.

In a macro scenario, as a future perspective, it is expected that not only the use of games, but any other method available and capable of involving students can gain their space, so that educational challenges can be overcome and a generation of engineers more aligned to the demands of 21st century society can be formed.

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Production of a Virtual event on Quality Management and Collaborative International Projects using Scrum as a Project Management Methodology

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Abstract

In a pandemic context caused by covid-19, the education had to adapt to a new global social-political scenario and find different ways to comply with society. In that sense, there is an increasing virtualization that boosts learning-teaching processes in virtual scenarios. The objective of this paper is to publicize the production of a virtual event that presents the results of collaborative international projects, developed by students from the Department of Production Engineering of University of Brasilia, in this time of social distancing. This research is applied, quali-quantitative and descriptive. As data collection technique to measure spectator's satisfaction, it was used a questionnaire, based on a SERVPERF model that measures service quality, that contemplates the evaluation of the criteria such as tangibility, reliability, promptness, security and empathy. The event had 164 people registered and 93 actives, the majority of them students from 4 courses that apply the PBL methodology, and develop projects in an integrated way. The satisfaction evaluation questionnaire was answered by 27 spectators. The average score for the general evaluation of the event was 9.22 on a scale that goes from 1 to 10, a result that displays a high satisfaction index by the spectators with the event. It is feasible to observe that the Scrum methodology was effective for the event project management.

Keywords: virtual event, quality management, collaborative international projects, project-based learning

1 Introduction

With the arrival of the first cases of SARS-CoV-2 pandemic to Brazil and in the middle of an international public calamity, the Brazilian government decreed a set of temporary actions aiming to contain the spread of the Covid-19 disease. One of them was the suspension of face-to-face academic activities in higher education institutions (Brazil, 2020). According to Ferreira (2020), this suspension led to a transformation in the regular functioning of higher education institutions with great impact on the entire academic community, especially on students.

As a consequence of the pandemic, in-person academic events were also impacted. Thus, remote teaching has become a reality, highlighting, therefore, the relevance of online academic events in the learning process. Events of this nature are an essential source in the search for new knowledge, by bringing together and presenting renowned professionals in the area of interest (Jesus et al., 2020).

Even with the impossibility of physical presence, some student-centered, active learning methodologies can be applied in the construction of education during this period. A widely used methodology is Project-Based Learning (PBL), which encourages the integration of new knowledge through the challenge of developing projects (Dewi; Kristanto, 2019).

For this reason, through this scenario of uncertainty and project development in the PBL context, stands out the use of the agile methodology, with the SCRUM framework. Traditional methods present robust planning, whereas agile methodologies have dynamic planning, which allows a quick and effective response to changes in the expectations of its stakeholders, so this way of managing projects reduces possible losses and increases gains. The SCRUM methodology was considered appropriate for this object of study, that are projects developed in disciplines of three and a half months duration (Scrumstudy, 2017).

This work aims to present the SCRUM management methodology to produce a virtual event and its results, based on the presentation of projects developed by students of the Production Engineering undergraduate at the University of Brasilia (UnB), within disciplines that apply to the PBL methodology. The online event permits the dissemination of results from projects developed in partnership with international institutions and concepts of Quality Management, brought by lectures given by professionals from nationally renowned companies.

This paper is structured in 5 sections: section 2 presents the literature review; section 3 shows the methodology; section 4 highlights the results and discussions and finally, section 5 presents the conclusions.

2 Bibliographic Review

This section offers the theoretical background needed to conduct the research.

2.1 Production of scientific events

The achievement of an academic event is the opportunity to deliver social value, generate knowledge and publicize brands, promoting true networking (Lacerda, 2019). According to Kotler (2000), one way to generate referrals for the company is "by engaging in events or activities that attract public attention." This source also points out that events are activities that attract attention and are an occasion for the development of items targeted to different audiences.

For Saito, Hiramoto, and Saito (2009), scientific knowledge made public, in forums, meetings or journals, promotes a discussion that enriches studies and it favors the advancement of science. To promote an event, a management methodology must be employed, because the event was built in the perspective of a project. The management methodology used in this study is discussed in section 2.2.

2.2 SCRUM methodology for project management

In a research conducted by Teixeira, Maccari and Kniess (2012), it was concluded that the main problems encountered in event execution are due to the absence of a responsible person or a management methodology. That's why it's essential to select the right tools to manage the event production project for this study: the SCRUM management methodology, "an extremely agile and flexible methodology" (Bissi, 2007).

SCRUM is based on adaptation and iteration, ensuring transparency in communication and continuous improvement (Scrumstudy, 2017). The method provides artifacts such as "product backlog" and "sprints", promoting the minimization of risks and offering users a quick and continuous evaluation (Silva and Silva, 2009).

To monitor the steps of the methodology applied in this research, the tools employed were an adaptation of Kanban, "one of the simplest and most popular tools in the agile world" (Dantas; De Aquino Junior, 2016) and the agile rites. The tools were accessed by the mentoring teachers and the work team simultaneously. The application of this model resulted in a virtual event, whose theme is explained in section 2.3.

2.3 Virtual events

Inserted in a pandemic context due to Covid-19, the event was held through virtual tools. Belloni (2002) explains that technologies are already part of all fields of social life, and that applies to education as well. It's fundamental to understand that social changes also modify the individual's perception and learning process, demanding radical transformations in the educational systems (Belloni, 2002). This statement is still relevant since, in recent studies, Mayes (2018) declares that the study of relations in the learning process can offer a deeper understanding of the society.

For De Sousa Oliveira Eleilde et al. (2020), this perception corroborates the idea that non-presence education is a trend that emerged suddenly during the Covid-19 quarantine period and tends to become even more common, so educational institutions are increasing their offers to meet this new demand. Consequently, there has been a transformation in the functioning of higher education institutions (Ferreira, 2020). Now with virtual communications the public can be better anticipated since it's understood that the situation should no longer be conceived as it was before. In this critical period, we must consider the virtual resources in a planned way (De Sousa Oliveira Eleilde et al., 2020).

The requirements for keeping students motivated through extracurricular activities is still demanded, along with the need for health's preservation: that's why an online event is an excellent alternative (Jesus et. al, 2020). It's also important not to forget the need to keep the audience's attention, considering the distraction scenario that a distance relationship can promote (Event Skift Brand, 2020). The event was produced in a virtual way, and was evaluated through the application of a questionnaire, which is explained in section 2.4.

2.4 Measuring results

To measure the public's satisfaction with the event held, a feedback of research should be conducted. With the application of a questionnaire in the academic event, it is possible to evaluate the audience's satisfaction and the quality of the lectures (De Freitas Faria et al., 2019). Hence, with a lot of planning, execution activities and verification, it's possible to refine processes and develop improvements to act on future experiences. This is the well-known PDCA cycle (plan, do, check, action) (Kume, 1993).

The results can be measured through questionnaires oriented to the satisfaction of the user of a service, since an academic event is a service too. One of the possible questionnaires in this sense is the one proposed by the SERVQUAL model, suggested by Manuela Krystyna Ingaldi (2017). The model proposes that the quality evaluated is given by means of "gaps". The gap is the difference between customer expectation and the performance of the service provided. (Salomi; Miguel; Abackerli, 2005). On the other hand, SERVPERF is another evaluation model that suggests that the quality is based only on the perception of the service, that is, the performance of the service provided is equal to the quality evaluation (Cronin and Taylor, 1992). The satisfaction measurement of the event was grounded on the SERVPERF model and the Net Promoter Score (NPS) indicator, an effective method for generating indicators and analyzing improvements (Oliveira, Vieira, Kovaleski, 2016).

The scope of the results presented at the event covers proposals originated from project disciplines that adopt the Project-Based Learning (PBL) methodology, in order to present solutions to real problems. This topic is detailed in section 2.5.

2.5 Project- Based Learning (PBL)

The premise of the event was the unveiling of results from interdisciplinary projects, developed within a process in which students are the main agent of learning. The learners are instigated to solve the problems presented (Delisle; Oliveira, 2000). For Barrows (1986), within the context of active learning such as Project-Based Learning (PBL), teachers play the role of facilitators of the process, but it's the student who must discover tools and methods capable of generating solutions to the problem at hand.

Therefore, new skills are developed and the learners become committed to the search for knowledge through curiosity and questioning that may arise (Barell, 2007).

However, for X. Du et al. (2009), in order to analyse the advantages and disadvantages of PBL, the most advantageous situation would be to have small-scale studies that provide details and large-scale studies that aim at representativeness. It would also be beneficial to have interinstitutional studies, both nationally and internationally.

Section 3 displays the complete methodology of the research design and project execution, seeking to clarify how the results were obtained.

3 Methodology

The methodology presents the research method and its structure.

3.1 Research Method

The research related to this article is characterized as, regarding its nature, an applied research, since it deals with a phenomenon that, in fact, generated knowledge of practical application (Silveira; Córdova, 2009). As for the objectives, the research is descriptive, because of the request of a semi-structured questionnaire to those enrolled in the event to measure the quality of the service provided at the end of the project. According to Fonseca (2002) this type of study is a survey research.

The research approach employed to present the results is qualitative and quantitative, since the results were subjected to a qualitative analysis of learning, considering that it uses an observation perspective, and concludes the reasoning with subsidy from the listed quantitative results of the questionnaire. The Qualitative analysis prioritizes the observation of the phenomenon (Silveira; Córdova, 2009), being the predominant objective of this study.

The main source for studying the subject were articles, other types of academic papers, books and manuals. A questionnaire was applied as a technique to collect data on the satisfaction of the event's audience. Out of 93 viewers who accessed the virtual event, 27 answered the questionnaire, representing a sample of 29% of the total viewers. The quality criteria evaluated were tangibility, reliability, promptness, security, and empathy. The research was structured in stages presented in the following section.

3.2 Structure of the research

It was structured in four consecutive stages, plus a management stage, simultaneous to the others, whose specifications can be seen in Figure 1.

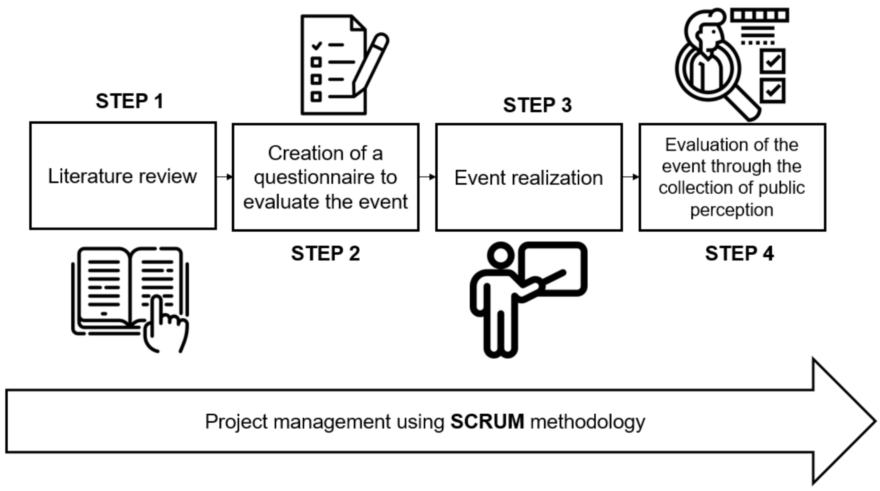

Figure 1. Structure of the research, done by the authors.

The first stage consisted of a literature review, whose search platform was the Web Of Science and Google Scholar, utilizing the keywords: "academic events", "technology", "marketing", "quality management", "questionnaire", "servqual", "servperf", "scrum", "research classification", "virtual events" and "virtual education". This examination was fundamental to define the objectives and describe the first steps toward them.

In the second stage, it was necessary to search for pre-existing and already validated questionnaires to develop the one that would be used to evaluate the event. With minor adaptations, the questionnaire was developed and based on the SERVPERF model. This was the best choice, since the participants could only be interviewed regarding the perception of the service, without a prior analysis of their expectations.

The third stage consists in hosting the event itself. As a premise, it was defined that the event would be virtual due to the Covid-19 pandemic and that registrations would be free. Negotiation techniques were used through compensation, where both parties win, so that partnerships and lectures could be established. To the event partners, the dissemination of their brands through the Instagram platform was a means of compensation, and to the lecturers, a certificate of participation was negotiated.

The literature was also an excellent support for the application of the event's development project management methodology. This, in turn, was pre-defined as an agile methodology, using the SCRUM framework. The agile methodology allowed the deliveries to be executed in small activity cycles (sprints) within a large project for feedback from the interested parties. The results of this research follow in section 4.

4 Results and Discussions

This section has the results of the event development project in terms of: (i) event planning, (ii) the event and (iii) post-event.

4.1 Event planning

To prepare the event planning, the team listed and divided the main tasks to be executed in columns of an online visual management chart: "backlog", "to do", "doing", "for evaluation" and "completed". In this way, a chart was made available to all members of the event organization team, consequently facilitating the identification of the requirements of the final product, as well as the activities that were being executed by the team.

This team held biweekly meetings with the stakeholders, over a period of three months, with the objective of aligning expectations and adjusting requirements. These meetings showed the need to define the theme, name, promotion and presentation platforms, number of speakers, and other factors of the event, such as the name "Quality Management virtual event". It was publicized by the social network Instagram and presented by Sympla Streaming.

Still in the planning stage, two lectures and a workshop were defined, as well as the need to bring to public notice the projects executed in the active learning disciplines of the Production Engineering course at UnB. The best ones were selected by the organizers of the event and professors, through the following pre-established criteria: social contribution of the problem, definition of the objectives, strategy adopted, cohesion in the development of the research, deadline performance and methodology employed. It is worth mentioning that all 8 projects designated for presentation, including the one that made it possible, were developed with the support of the Project-Based Learning (PBL) methodology. The activities involved in the event are displayed in section 4.2.

4.2 The event

The academic event was developed according to a pre-established schedule and occurred on two consecutive days, November 25 and 26, 2020, lasting three (3) hours each. The organization team took charge of the event, introducing the workshop, the lectures, and the projects. The choice to hold the event in two days was the result of a previous study that found the need to divide a large event into sub-events, so that the public's attention would be improved (Event Skift Brand, 2020).

The event had 164 people registered and 93 actives, counting with the presence of 52 participants simultaneously during the online presentations. This process helped in the preparation of questions to the lecturers, in order to contribute to the development of the activity. The lectures were given by representatives of three companies that are exponents in each of their fields. Regarding the 8 projects, they were presented by students from 5 different courses of the Production Systems Projects (PSPs) from the Production Engineering undergraduate at UnB. These disciplines belong to the areas of Research Methodology for Production Engineering; Personal Finances, Statistical Probability; Information System applied to Production Engineering with focus on System Requirements Surveying; Quality Management; and Project Integration Management.

It is noteworthy that the projects presented were interdisciplinary, so that the 8 teams from the 5 different disciplines worked in an integrated way to achieve the exposed results. Besides, some of the proposed themes involved international partnerships with Aalborg University, Denmark, for the Mobile Education project and

Esprit University, Tunisia, for the PUMA project (Unified Platform of Active Methodologies, acronyms in Portuguese).

The projects presented were evaluated in real time by the event's audience and the teachers of the disciplines related to the projects, who were part of an evaluation panel. This made possible that the best ones could be awarded as a form of incentive to the students. The teams' scores were given by the following weighted average:

$$M = NPG + 2*NPROF \quad (1)$$

where M is the team's final average, NPG represents the average of the scores of the event's audiences and NPROF represents the average of the teachers' scores. The teachers' grades had a greater weight in the team's final average, since a more technical content was sought in the awarding of the projects presented.

The event was guided by concepts of Quality Management; therefore, a questionnaire was applied as a means to understand if the service provided met the public's expectations.

4.3 Post-event

As previously explained in the methodology, the evaluation counted on an adaptation of the SERVPERF model, because the questionnaire pre-established by this model aims at a physical service, which is tangible. Accordingly, the quality criteria of tangibility, reliability, promptness, security and empathy (Salomi; Miguel; Abackerli, 2005), were employed to develop the questionnaire for the service of production of a virtual event, as presented in Table 1.

Table 1. Criteria adapted from the SERVPERF model for producing a virtual event.

Criteria	Related Questions
Tangibility	The workshop, lectures and projects presented were fruitful, presented visually pleasing slides that were easy to understand?
Reliability	Did the event faithfully meet its opening and closing times?
Promptness	Did the event ceremonial adequately inform about schedules, attend promptly to the public, and were they organized?
Security	Was the organizers' contact with the public easy and safe, and did they offer interesting raffles and clear and appropriate promotion?
Empathy	Was the event dynamic, did it meet the audience's expectations, and was it able to keep their attention?

The questionnaire was previously validated with a group of 10 people to be applied later. The public's understanding of the questions was tested with male and female representatives. The questionnaire was answered by 27 people, 37.03% female and 62.96% male. This means an adherence of 29% of the total audience to the questionnaire. However, of the total of 93 people, only 52 were able to fully evaluate the event, as they participated in the event in its entirety. In this case, the sample represents approximately 52% of 52 people. The results are presented in Figure 2.

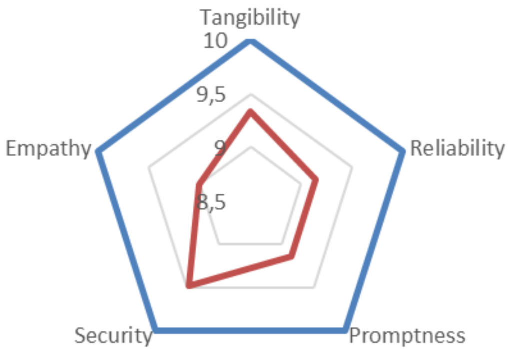

Figure 2. Quality Criteria evaluated by the SERVPERF model, chart elaborated by the authors.

Through the scores attributed to the evaluated criteria, it is understood, therefore, that interactivity and dissemination (security criterion) and the use of the lectures, workshops and projects (tangibility criterion) were the best evaluated, with averages of 9.48 and 9.33, respectively. Punctuality (reliability criterion) and ceremonial performance (promptness criterion) were tied in the evaluation, with an average of 9.14. The ability to entertain, educate, and keep the audience's attention (empathy criterion) resulted in the lowest average, 9.00. The overall average for the criteria was 9.22.

The lowest scores were attributed to the reliability, promptness, and empathy criteria. The lowest individual score given in the whole evaluation was 6.00 for reliability, more specifically punctuality. That was because some factors are beyond the organizers' total control and the punctuality of the lecturers was one of them.

All in all, on a scale of 1 to 10, the criteria were well evaluated as there was no individual average lower than 9.00. Figure 1 shows the overall evaluation of the event.

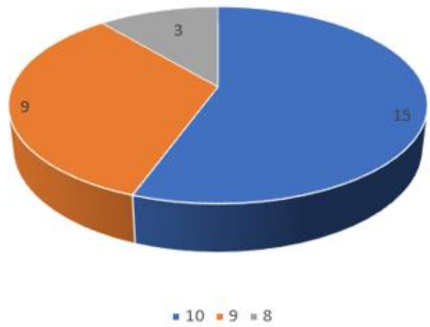

Figure 3. Overall evaluation of the virtual event, provided by the authors.

The scores were attributed as follows: 15 people gave a score of 10.0 as a general evaluation; 9 participants gave a score of 9.0 and 3 people associated the event with an 8.0 score. In the overall evaluation, the average grade given was 9.44 (on a scale of 1 to 10). Using the understanding given by the Net Promoter Score (NPS) indicator, by a simple calculation, % promoters (scores 9 and 10) - % neutrals (scores 7 and 8) - detractors (scores 1 until 6) = NPS. The evaluators who gave a score of 1.0 to 6.0 were considered detractors, in other words, they were not satisfied. Those who gave a score between 7.0 and 8.0 were considered neutral. On the other hand, the evaluators who gave a score between 9.00 and 10.00 were considered promoters, that is, they were satisfied.

It's understood that, according to the survey results, among the respondents, 24 were promoters and only 3 neutral ones (Oliveira, Vieira, Kovaleski, 2016).

In order to complement the results obtained and show the opinion of the viewers and the presenters, anonymous feedback testimonies were included, transcribed below, which reiterate the result.

"Very good event! We learned a lot from the lectures, in addition to having an overview of what was done in the course. Very positive!"

"Wonderful and very organized event. The organizers were very competent."

"Excellent event! Of course, dynamic and very knowledgeable."

In addition, the organizers approached their experiences as something that a new perspective of learning in the team, through an active methodology and, where they became protagonists of the teaching process in Production Engineering and its projects in a pandemic context. An ease was added in the general understanding of teaching that they did not have before.

5 Conclusion

Despite the huge impact in education and teaching due to the Covid-19 pandemic, it was possible to adapt to the new reality by using a virtual event as an option for learning strategy. In this article we present our methodology for the project management and the results obtained by planning, executing and evaluating of the event, therefore, fulfilling our research objective.

The activities of the event were executed by a team of students from the discipline of Projects related to the Quality Management (PSP5), in a way that the active learning methodology was a fundamental agent in the development of the event during this period of pandemic. In addition, the PBL methodology allowed a greater protagonism of the students in the organization of the event.

As a form of project management, the SCRUM framework succeeds to meet the expectations of a service project. The possible disappointments regarding the results and evaluations were avoided by periodically aligning the needs of all stakeholders, until the final stages of the project. The event could be considered satisfactory, based on the results obtained in the post-event, a general average of 9.44, on a scale of 0 to 10 was obtained, becoming a very positive evaluation by the participants.

In relation to the objectives, were achieved by presenting the results in interdisciplinary international projects from 3 different countries. In addition, the lectures and the workshop contributed to the teaching-learning of Quality Management concepts, in a way that didn't cause any health risk to any stakeholder.

As a limitation of the research, we can underline the little coverage of the event, since it was 100% online and no physical means of divulgation was used due to the pandemic conditions. Furthermore, the themes of the lectures and the workshop were restricted to the Quality Management areas.

Finally, as future work, it's recommended to expand the themes of the lectures and workshops, aiming to cover other areas besides Quality Management, that is, an event with a wider range of themes and audiences. Also, in a non-pandemic scenario, we suggest a greater divulgation of the event, relying on physical means, as well as the realization of a hybrid event, with remote and in-person possibilities.

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Student motivation in the first year of University: findings from the implementation of a PBL project for a real context

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Abstract

Student motivation is a key dimension for first year students at University. Project-based Learning (PBL) is seen as an effective teaching and learning approach to enhance student motivation and engagement. This paper describes the results from the implementation of a PBL project that was developed for a real context – a non-profit social organization that works with children. The project included, for the first time, two curricular units from the field of Psychology and Education Sciences, integrated in the first year of the study plan of the Social Education degree programme at Portucalense University, Portugal. The paper describes, on the one hand, the objectives, planning and assessment of the PBL experience from a curricular and pedagogic point of view and, on the other hand, presents students' perceptions about their PBL experience. Data collection was based on an online survey to students, at the start of the PBL project and after its conclusion, and a content analysis of the project reports of the groups. Findings reveal the importance of the development of the project for a real context and with a specific target audience as the main issues that enhanced student motivation and engagement in the courses involved in the project. Working in teams, the opportunity to develop generic competences, the stronger link between theory and practice, student resilience, teacher support and continuous feedback are also mentioned as important features of PBL that impact student motivation in the first year of University.

Keywords: Active Learning; Project-Based Learning; Academic Motivation; University Students.

1 Introduction

University entry represents one of the most important, ambitious, and difficult stages in early adulthood (Arnett, 2004). For the majority of young adults, this stage represents the search for a higher educational level, the establishment of personal and professional goals and the creation of future work prospects (Blanco et al., 2008). In order to deal with these multiple changes, challenges and demands, students must have an adequate and consistent personal structure and effective adaptation skills (Bewick, Koutsopoulou, Miles, Slaa, & Barkham, 2010). Nevertheless, students are not always prepared to face them. Very often the university context creates stress and anxiety among vulnerable students who are more exposed to the challenges that the competitive environment usually generates (Reddy, Menon, & Thattil, 2018). In fact, going to college is perceived as an essential investment in the career for any student and higher education has become a universal and mass system (much bigger, less exclusive and more important). This expansion means that today, more than ever, educational institutions favour and create a competitive environment (Araújo et al., 2006; Davies & Hammack, 2005; Granado et al., 2005). This causes an overwhelming emotional burden that leaves students with minimal opportunity to relax and recreate, which can negatively affect them in performing tasks effectively and consequently affects their academic performance (Liu & Zhao, 2018; Trigueros et al., 2020), or it may even lead to dropping out of higher education (Sosu & Pheunpha, 2019). Considering this, universities have the mission and the duty to support students to become life-long learners and versatile experts in their own fields, fostering and stimulating the development of lifelong learning skills, such as problem solving and critical thinking, essential to increase students' competitiveness in the labour market (Dolmans, Loyens, Marcq, & Gijbels, 2016). Moreover, according to the Bologna declaration, successful learning and studying in higher education should involve students in deep learning (Asikainen 2014), by allowing them to be responsible and to acquire autonomy during the learning process that are essential skills for lifelong growing knowledge and practice (van den Hurk, 2006).

Traditionally, the teaching methods that prevail in different educational contexts, namely at the university, are based on a limited practical applicability of knowledge and a pre-eminence of rote learning. Thus, students are faced with fictional situations designed by the teacher that often differ from real situations. Furthermore, the education system often pays more attention to the results achieved by students, without worrying about the mental processes they have used to assimilate information and/or whether there is a clear applicability of the assimilated knowledge by students to various everyday situations. For this reason, one of the aspects that must be promoted from the educational point of view is the predominance of significant learning, with the aim of developing conscious and reflexive learning by students that will allow them not only to consolidate their own knowledge but also to establish the information, skills and values that they will have to assimilate and apply in the future (Trigueros, Padilla, Aguilar-Parra, Lirola et al., 2020; Zohar, & Barzilai, 2013; Rodríguez-Sandoval, Vargas-Solano, & Luna-Cortés, 2010). The analysis of the importance of student motivation to the educational context and academic achievement should also be done considering student's performance and engagement, namely in achievement-oriented educational settings, where self-efficacy can be seen in the student's perceived confidence in achieving certain goals. The sense of self-efficacy helps to determine what choices students make, how much mental effort they invest and how long they persist in a task (Schunk & Pajares, 2005). However, few studies have shed light on the mechanisms that manage how different types of motivation (i.e., intrinsic motivation, extrinsic motivation, and self-efficacy) affect learning engagement and performance. In a very recent study involving 1930 medical students in China (Wu, Li, Zheng, & Guo, 2020), results showed that the total effect of intrinsic motivation on academic performance was larger than that of extrinsic motivation. Moreover, significant indirect effects of either intrinsic or extrinsic motivation on academic performance were found through learning engagement. Besides, both intrinsic motivation and extrinsic motivation predicted self-efficacy, the direct effect of self-efficacy on academic performance was not significant. This suggests the need to develop motivation-related counselling methods to promote the academic achievement for different groups of medical students.

Problem and project-based learning (PBL) is an educational approach in which complex authentic problems serve as the context and stimulus for learning. PBL is designed to encourage active participation during learning, being associated to positive effects on academic self-efficacy (self-control efficacy, task-level preference) and academic failure tolerance (behavior, task-difficulty preference) as academic motivation (Yune, Im, Lee, Baek, & Lee, 2010).

Therefore, the aim of this study is to analyse and discuss student motivation based on the implementation of a Project-based Learning (PBL) approach with first year students of the Social Education programme at Portucalense University. Specifically, this paper describes the results from the implementation of a PBL project developed for a real non-profit social organization that works with children, discussing students' perceptions about the usefulness of this methodology in their learning of technical and soft skills, academic motivation, academic performance and academic success. The paper is organized in four main sections. In the first part, a brief presentation of the state of the art on student motivation in PBL is presented. Section two focuses on the methodology of the study. It includes the research questions and methods and a brief description of the context of the study. The third and last section of the paper present and discuss the results of the study, drawing on findings from the data analyses and its relationship with the literature review in the field.

2 Methodology

2.1 Research questions and methods

The aim of this study is to analyse and discuss student motivation based on the implementation of a Project-based Learning (PBL) approach with first year students of the Social Education programme at Portucalense University.

To attain this goal, the following research questions were defined:

- What are students' perceptions about their PBL experience?
- How does PBL enhance student motivation?

- What are the key dimensions for student motivation in the first year of university?

The study followed a qualitative approach. For data collection, an online questionnaire, with open-ended questions, was applied to students, at the start of the PBL project (initial perceptions) and after its conclusion (final perceptions). The questionnaire is based on previous research developed by the authors about the impact of PBL on students' learning (Fernandes, Abelha, Albuquerque, & Sousa, 2020; Fernandes, Abelha, Fernandes, & Albuquerque, 2018). Besides the questionnaire, a document analysis was also used, namely regarding the project reports developed by the groups. The participants in the study include 10 students (8 female, 2 male) enrolled in the two curricular units.

2.2 Context of the study

The study took place in the 1st semester of the 1st year of the Degree in Social Education at the Portucalense University and involved two curricular units – Cultural Animation in Education Contexts (CAEC) and Developmental Psychology 1 (DP1). The main purpose of the PBL project was to develop an cultural animation programme for children and/or adolescents who attend a non-profit social organization, based on the principles of the two curricular units involved. The mission of the association involved in the project is to promote the education of children and young people from vulnerable families aiming for their social inclusion. The mediation with the the association and information about its mission and needs of the target population, essential for the development of the PBL projects, was given by a third-year student of the Social Education programme, who was carrying out her curricular internship at the association. This student will also be responsible, in the future, for the implementation of the activities of the PBL projects (planned by the first-year students) at the institution. It should be noted that this particularity proved to be an element that triggered higher motivational levels among the students.

The working groups, comprised 2 to 3 students in a total of 4 groups (*N*= 8 female and 2 male students), developed four intervention projects aiming: 1) working on steriotips related to religion, race, sexual orientation and weight and promote social inclusion of adolescents; 2) making young people aware of their rights and duties, working on the concept of freedom; 3) to promote civic participation with a focus on environmental education and also to give pedagogical support as a way of reinforcing the work done in the classroom in most difficult learning activities and contents; and 4) to contribute to academic success and to the personal development of young people, namely by defining more effective study strategies through playful activities.

To monitor the progress of the project and the students' learning, several checkpoints, also known as Milestones (see Table 1), were established by the teaching team to support the students during the PBL project, as well as to enable moments of sharing and feedback among students and teachers involved.

Table 1. Milestones

#	Week	Date	Milestone
1	Week 2	22.10.2020	Presentation of the PBL Project
2	Week 3	29.10.2020	Guest Lecture: Presentation of the association and its mission
3	Week 7	03.12.2020	Project Monitoring Session - Intermediate Presentation
4	Week 11	05.01.2021	Submission of Preliminary Report (Moodle)
5	Week 10	07.01.2021	Feedback on the Preliminary Report
6	Week 11	12.01.2021 14.01.2021	Final Project Presentation
7	Week 12	21.01.2021	Final Report Submission (Moodle)

The final assessment of the students in each CU is based on two components: one related to the student's final classification in the project (40%) and another related to the classification resulting from the student's continuous assessment in the CU (60%).

3 Results

This section presents the results of the study, which are organized in two main subsections: the first part, presents data from students' expectations about their PBL experience; the second part, presents data from students' perceptions at the end of their PBL experience.

3.1 Students' expectations about their PBL experience

In the first week of the project, after the PBL approach and the objectives of the project were presented, students were asked to complete a short online questionnaire about their expectations regarding their PBL experience. It was interesting to notice that when students were asked to state what motivated them the most, most of the answers referred to the opportunity to collaborate with the non-profit social organization and its target audience – children. The possibility of developing a project that can have an impact on others, was also mentioned as a motivational issue. The following quotes from students confirm this:

> *What motivated me the most in this project was the fact that I could make a difference in someone else's life and, in that way, I can contribute to their journey in a positive manner.*

> *What motivated me the most was knowing that I could help and teach children and youth or even adults with a theme that touches me personally.*

> *Being able to work and carry out a project for children.*

This same idea was also present in students' answers when they were questioned about what they expected to be the most positive and less positive aspects of this PBL experience. Regarding the positive aspects, being able to work with a real context and to develop a project for a specific target audience, using their own creativity, was stated by most of the students:

> *Communicate, interact with others and above all help in a positive way.*

> *The positive aspects of this project are being able to really help a real institution, it is also being able to put our knowledge and creativity into practice. Another positive aspect is that we can teach and educate people with the project.*

> *The most positive aspect for me is his goal, which makes us help children to develop their emotional capacities.*

Students had difficulty in identifying or anticipating the less positive aspects. Most of them answered that they could not see any negative aspects. However, one student was able to identify the workload and the pandemic situation of COVID-19 as possible barriers for the success of the project.

> *The less positive aspects are the work that it will take, because a good project takes a lot of work but it ends up rewarding at the end and also the problem of COVID that ends up getting in the way despite being directly related to the project itself, it ends up interfering in it negatively.*

3.2 Students' perceptions at the end of their PBL experience

In the same way, after the project was concluded, students were asked to share their perceptions about the PBL experience. Data presented in this section is based on a content analysis of the open-ended questions of the online questionnaire applied to students and some of the project reports delivered by the groups, which included a final reflection of the overall PBL experience. Considering the research questions defined for this study, it was possible to identify three main categories that explore how PBL enhanced student motivation. These categories include: 1) stronger link between theory and practice; 2) working in teams and developing competences; and, finally, 3) student resilience and continuous improvement.

3.2.1 Stronger link between theory and practice

Students were aware that PBL provided a stronger link between theory and practice, this is, the continuity between training and the professional future. The practical dimension of the project, which put emphasis on the process, rather than on the product or the end result, was also visible in students' final perceptions about the PBL experience.

The added value of this PBL is to make a project that can be used in practice, that is, the project was made to be used and not just evaluated and placed in the corner.

It was more practical work

The fact that we never carried out an interdisciplinary project was challenging, as we had to base it on the principles of Developmental Psychology and Cultural Animation in an Educational Context. (Project Report of Group 2)

The project also allowed students to understand the diversity of approaches to the same reality, both in the conceptual framework that is given (two different curricular units), as well as in the products that result from the activity. This results in greater richness in the learning process and in the result itself. It brings benefits for institutions and individuals, as there are no better perspectives or worse, but just different focuses of analysis.

All projects contributed to learn new and different things, as each project was different from each other.

Throughout the project, it was possible for us to acquire new knowledge, as well as to develop communication skills. In the course of this work, some difficulties were felt, which were essentially related in the proper management of our time and in the selection and organization of the information collected. However, we found that the development of a close and cooperative relationship, as a group, were essential characteristics, not only for the elaboration and completion of this project, but also so that we can face the next challenges, overcome new adversities and always respect the importance of individual work in the production of group work. (Project Report of Group 2)

3.2.2 Working in teams and developing generic competences

PBL is all about working in teams and this implies the development of generic skills, namely communication, leadership in achieving goals, concern for quality and effectiveness, self-assessment and hetero-assessment skills, ability for conflict management, commitment, organization and planning. When asked to identify the most positive aspects about the PBL experience, teamwork was the most referred idea, as seen through the following evidence from students:

The fact that we must work in a group, which is something that we will have to deal with during our future work.

The capacity for creativity, commitment and organization as a group.

Working as a team, creating the project itself because I think it was good for our learning and also creativity

Based on the analysis of student project reports delivered by each group, it was possible to verify that some groups (two out of four) included a final reflection about their learning process, and this necessarily focused on issues related to working in teams and the development of interpersonal competences. These two excerpts from the project report of group number 3 confirm this.

"The challenge of creating a project within the curricular units of Cultural Animation in Educational Contexts and Developmental Psychology I, aroused great interest in addition to many doubts. My two colleagues and I, at first, were kind of lost in planning and diagnosing needs, I believe that it took us some time to understand for sure what we were supposed to do for our project on behalf of the Association "My place in the world", but with some tips from the teachers and with our teamwork we ended up getting there and reaching consensus on what we would do to respond to the needs of our target audience, the young people of this association. "1, 2, 3 is your turn", it will be marked as the first project that I developed as a team – (Project Report of Group 3)

"I liked to develop this project because it was something that challenged me, I had never done anything like this, in fact at the beginning I felt that I was half lost because I didn't even know what I was going to come out. I knew that a project was time consuming and something that required a lot of work, but in fact I had no idea of what the development and creation of a project really was. I think the fact that the project was aimed at young audiences was something positive, however, also with its difficulties, but I think that here Elsa's help, in saying what she liked working with the kids, made things a little easier. The help of my colleagues was also important because they gave me ideas, they gave me their opinion that for me it was important to develop my activity. And finally, it was the help of Professor Sandra and Professor Ana, who helped us to go the right way at the beginning of the project, giving us the right guidelines and always trying in some way to help us throughout the project." – (Project Report of Group 3)

3.2.3 Students' resilience and continuous improvement

The third category that could be identified based on the data analysis is students' resilience and continuous improvement. Being able to overcome oneself is a basic motivational component (reasons for personal fulfilment imply that the context can know the individual and what he values, believe in skills and promote autonomy). Two students referred exactly to this aspect, when identifying what was most positive about the PBL experience:

Overcoming myself!

Developing my first project and being successful!

To motivate someone implies the proactive involvement of individuals and the recognition of the practical / concrete relevance of the activity (identification with the objectives to be achieved). It is a continuous process and a journey of continuous improvement. Therefore, the importance of feedback for the implementation of improvement processes is also recognized by students.

"This project was undoubtedly something challenging and new. I was not at all prepared and it was quite scary at first. However, as I and my colleagues developed it, it became easier because I was enjoying working. Above all, it helped me to develop my creativity, as well as discover strengths in terms of work that I didn't know I had. Although the target audience is defined and, at the outset, it is something positive, it proved, on the contrary, to be something that made our work difficult. However, these types of challenges are important and always end up being beneficial, especially in this first stage of our academic life. The project is mine, my colleague X's and my colleague X's, but without a doubt that without the help of Professor Sandra and Professor Ana we would still be at the beginning of its realization. "– (Project Report of Group 3)

"In short, the development of this project contributed positively to our academic development, gave support to strengthen our background and our professional and, also, personal identity and the development of our critical thinking". (Project Report of Group 2)

4 Final remarks: Key dimensions of PBL to enhance student motivation in the first year of university

As recognized by students involved in the present study, PBL helps students to develop effective problem-solving skills and to become active participants in their own learning by enabling them to construct knowledge, as sustained by previous studies (Levett-Jones, 2005; Loyens, Magda, & Rikers, 2008). Motivated by the opportunity to collaborate with the non-profit social organization and its target audience (children), first year students of the Social Education programme at Portucalense University mentioned that the possibility of developing a project that can have an impact on others was the main motivational drive of their involvement in the project tasks. Students were aware that PBL provided a stronger link between theory and practice and this recognition allowed them to put emphasis on the learning process, rather than on the product or the end result associated to the assessment process.

Academic motivation is also promoted by working in teams, which supports not only a deeper understanding of contents, but also engages students in strategies that allow them to work collaboratively in solving problems, reflecting on experiences, and engaging in self-directed inquiry (Hmelo-Silver, Duncan, & Chinn, 2006; Paris & Paris, 2001). Students referred assertive communication, leadership in achieving goals, concern for quality and effectiveness, self-assessment and hetero-assessment skills, conflict management skills and commitment as the most important soft skills acquired because of this teamwork.

Self-regulatory skills are of little value if students do not motivate themselves to use them. In fact, academic motivation implies the proactive involvement of students in the learning process and this, in turn, implies that students recognize the practical relevance of the activity and the objectives to be achieved. One of the most studied self-motivational beliefs is self-efficacy, which refers to an individual's beliefs about his or her capabilities to learn or perform behaviour at a defined level (Bandura, 1998). Self-efficacy beliefs are hypothesized to be mediators of behavioural change (Zimmerman, 2002; Pintrich & Schrauben,1992) and develop from four sources: direct experiences, vicarious experiences from observing peers, persuasion by others, and personal physiological reactions (Bandura, 1998). Supporting students to learn is the super ordinate aim of higher education and the teacher is a key figure who can mediate the stress associated to the challenging experiences faced, especially by the first-year students at the university (Darling-Hammond, 2000; Rivkin, Hanushek, & Kain, 2005; Mahlerl, Großschedl, & Harms, 2018). The role and support of the teacher in classes is also a key issue. This issue was also recognized by students in our study, who considered the teachers' feedback and monitoring of extreme importance for the implementation of improvements in the groups' projects and for the development of self-regulated strategies to effectively set goals, plan and use strategies to achieve the goals established, to manage their resources, and monitor and evaluate their progress at various stages of the learning process. As previous findings already suggested, when students are responsible for their own learning, they are also more motivated to learn (Gabr & Mohamed, 2011), have higher levels of intrinsic goal orientation and task value (Sungur & Tekkaya, 2006), and use more elaboration strategies, critical thinking, and metacognition (Sungur & Tekkaya, 2006). In sum, they acquire autonomy in learning that is essential for lifelong growing knowledge and practice (van Den Hurk, 2006).

Most of the students had difficulty in identifying or anticipating the less positive aspects of their involvement in a PBL project. Nevertheless, the anticipation of possible obstacles for the achievement of the objectives established is essential to maintain motivation when these obstacles occur, namely to reorganize the behaviour necessary to achieve these objectives. In fact, students with high levels of self-efficacy are more willing to take on challenging tasks (Zimmerman, 2000). When facing a difficult learning task, a student with high self-efficacy is more likely to participate actively, work harder, remain more problem focused, and persevere for a longer time than a student with low self-efficacy, who is more likely to become frustrated and give up (Papinczak, Young, Groves & Haynes, 2008). Therefore, increasing students' self-efficacy beliefs, as happened in the present study and recognized by participants as the most important achievement of this PBL experience (*"Overcoming myself!"* and *"Developing my first project and being successful!"*), will improve students' motivation and SRL skills, and vice versa.

Summing up, the reported PBL experience contributed to the growing evidence that this methodology promotes active learning and students' intrinsic motivation, which enhances deep learning (Dolmans, Loyens, Marcq, Giibels, 2016). At this level, self-efficacy beliefs seem to affect students' motivation through self-regulatory processes. Monitoring students' development in these skills and giving them feedback could be beneficial for the cognitive achievement, especially for students with learning difficulties and lacking study skills (Demirören, Turan, & Öztuna, 2016).

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The perception of students from a higher education institution regarding the importance of education in OSH subjects during COVID Pandemic

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Abstract

Work safety in general is a set of methods that aim to control the risks associated with the workplace. In engineering courses, this discipline is mandatory; however, non-engineering courses are presented optionally. Thus, as not all students have contact with the discipline of safety and health at work, the need arises to understand the perception of students about this discipline. For this, a questionnaire was developed to capture the perception attributed to occupational health and safety. This questionnaire was made available online, via institutional email. The work was carried out at a Portuguese public university. 275 students (80.2% of the expected) enrolled in 17 undergraduate courses (those that are not related to engineering) answered the questionnaire. For statistical analysis, courses were grouped into clusters (N = 10) according to pre-established criteria. As results it was noticed that: (1) in relation to curricular preferences, cluster 3 presented better indicators about the importance of Safety and Health at Work, while cluster 5 presented the worst indicators of importance; (2) in cluster 7, 100% of respondents stated that safety is of utmost importance and in return, only 40% stated the same in cluster 4. It is concluded that there is a difference between the perception of the importance given to Safety and Health at Work among the studied clusters. This highlights how important the dissemination of content is in relation to safety, a factor that has the potential to reduce the perceived disparity among students of the various courses.

Keywords: Curricular Unit; Education; University; Safety Perceptions; Undergraduate Students; Portugal

1 Introduction

In Portugal in 2019, approximately 305,000 young people (those aged 15-24 years) were engaged in some form of paid activity (Instituto Nacional de Estatística, 2019). In the last report of occupational accidents, in 2018 of the approximately 196,000 accidents recorded (<18 to >65 years), 6.6% (n = 20.100 occupational accidents) occurred among young people aged 15-24 years (Instituto Nacional de Estatística, 2018a). In the same period, 4 young workers lost their lives performing some work activity (Instituto Nacional de Estatística, 2018b). The seriousness of this situation is evidenced when studies carried out in Finland (Salminen, 2004), Canada (Chin et al., 2010) and Australia (Pisaniello et al., 2013) identified that young workers had more accidents than adult workers. Not unlike previously noted, in Portugal young people suffered 2.84 times more accidents at work than adults (Instituto Nacional de Estatística, 2018a). It is important to note that most of the jobs occupied by young workers are those that do not require specialized technical skills and, therefore, such establishments, being small businesses, provide little or no notions of safety (Delp et al., 2002). In this sense, relying on the training provided by the company can be somewhat weak and it favours work accidents among the young population even more (Chin et al., 2010). Another possible explanation for this situation would be the general assumption that such working environments, as they are simple and basic activities, offer no or little risk to young people and that is why there is a disregard on the part of employers towards them (Chin et al., 2010).

Having exposed this scenario, it is evident that safety education is a fundamental and urgent matter (Chin et al., 2010) and, therefore, increasing students' knowledge and capacity in relation to this theme is an indisputable aspect not only in relation to the reduction accidents, but also to cope with day-to-day activities. Given this context, the University of Minho provides the teaching of occupational safety in two different ways. The first, in courses “more connected” to industry, such as Engineering and Chemistry, for example, the subject of safety is a mandatory part of the curriculum. However, for those courses "further away" from the industry, such as International Relations and Sociology, the discipline is provided as optional/no mandatory.

In view of this, this study aimed to assess the perception of undergraduate students enrolled in those courses considered to be "further away" from the industry in relation to Occupational Health and Safety.

2 Materials and Methods

2.1 Description of the Study Area

The study was carried out at the University of Minho, a Portuguese public university located in the north of the country. The University of Minho (UM) is divided into three campuses. Two located in the city of Guimarães (Campus de Azurém and Couros), and another located in the city of Braga (Campus de Gualtar).

Regarding the sample size, it was designed as proposed by Israel (1992), considering aspects such as the population size (N = 2427), the confidence level (95%) and the sample error (5%). From the parameters listed above, the ideal number of participants was established in 343 individuals. However, at the time of the end of the period to respond to the survey (October 15, 2019), the total number of study participants was 275 (80.2% of the expected).

The data were collected through the Survio platform and analyzed using Microsoft Excel 2019.

2.2 Study Population and Sample Size

Seventeen undergraduate courses participated in this study, totalizing 275 students. These 17 participating courses were chosen because they are the only ones to offer Occupational Health and Safety as a curricular unit option. The engineering courses were not present in this study due to the curricular unit "Occupational Safety and Health" being a mandatory component of the disciplines grid. In order to optimize the analysis process, 17 participating courses were grouped according to the compatibility of the curricular units available / offered as an option, resulting in the creation of 10 clusters (Figure 1).

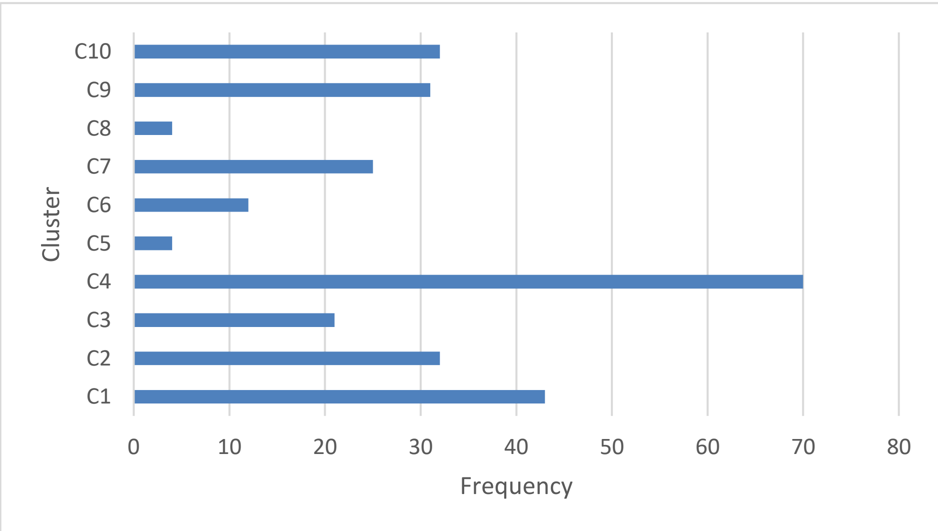

Figure 1 - Clustering and number of participants

2.3 Survey Instrument

A questionnaire was developed as a tool in order to determine the students' perception regarding the importance of teaching the subject of "Health and Safety at Work". The questionnaire composed of 15 questions (closed) was structured on the Survio platform. The survey is organized in 4 sections (Figure 2) and was validated by the professors of the Industrial Engineering department, Susana Costa and Isabel Loureiro.

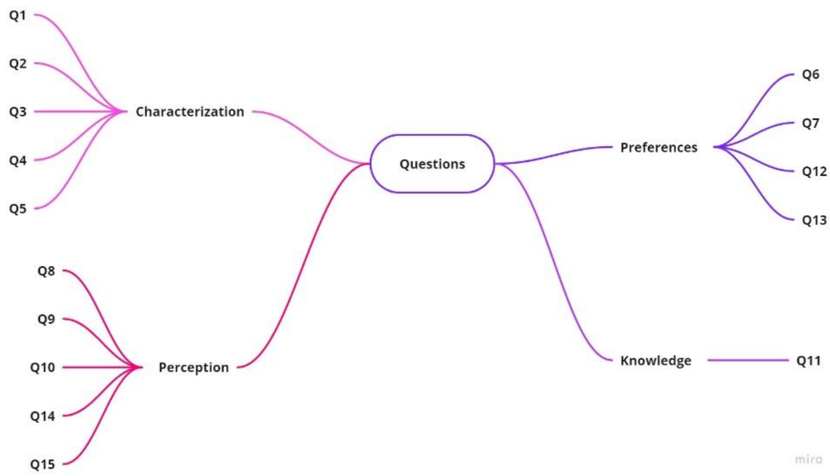

Figure 2 – Distribution of the questions

The first part of the questionnaire, consisting of 5 questions, refers to the characterization of students. The second section asked students about their preferences. The third part of the survey asked them about their proper perceptions and the fourth and last, their knowledge regarding the theme. The disclosure of the survey took place between September 21 to October 15, 2020, and took place through the university's institutional email.

2.4 Data Collection and Analysis

The information was collected randomly and analyzed using descriptive statistics techniques (averages and frequency count). In order to fulfill its objective, only parts 1 (Characterization) and 3 (Perceptions) were investigated (Figure 2). That said, the questions used for this purpose are presented in Table 1.

Table 1 – Frequency distribution of students by demographics.

<table>
<tr><th>Variable</th><th colspan="2">Frequency</th><th colspan="2">Percent</th></tr>
<tr><td>Q3 - Academic Year</td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>Year 1</td><td colspan="2">70</td><td colspan="2">25,5%</td></tr>
<tr><td>Year 2</td><td colspan="2">73</td><td colspan="2">26,6%</td></tr>
<tr><td>Year 3</td><td colspan="2">131</td><td colspan="2">47,8%</td></tr>
<tr><td>Q4 - Age Group</td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>17-21</td><td colspan="2">239</td><td colspan="2">86,9%</td></tr>
<tr><td>22 -25</td><td colspan="2">17</td><td colspan="2">6,1%</td></tr>
<tr><td>>25</td><td colspan="2">19</td><td colspan="2">6,9%</td></tr>
<tr><td></td><td colspan="2">Yes</td><td colspan="2">No</td></tr>
<tr><td>Q5 - Work Experience</td><td colspan="2">40,7% (n=112)</td><td colspan="2">59,3% (n=163)</td></tr>
<tr><td>Q8 - Regardless of your choice in relation to the options of curricular units (UCs) available, what is the degree of importance that you attach to each one for the work context?</td><td colspan="4">Moderate</td></tr>
<tr><td>Q10 - Is Occupational Safety important to you?</td><td colspan="4">8,78 (1 to 10)</td></tr>
<tr><td></td><td colspan="2">Yes</td><td colspan="2">No</td></tr>
<tr><td>Q14 - In view of the current COVID-19 pandemic, do you consider that workers' safety issues should be more guarded by companies?</td><td colspan="2">98,9% (n=272)</td><td colspan="2">1,09% (n=3)</td></tr>
<tr><td></td><td>Most Important</td><td colspan="2">Equal Important</td><td>Least Important</td></tr>
<tr><td>Q15 - For you, since the emergence of the current Pandemic, do you attribute more, less or equal importance to Safety and Health at Work?</td><td>83,6% (n=230)</td><td colspan="2">16% (n=44)</td><td>0,3% (n=1)</td></tr>
</table>

3 Results and Discussion

The analysis of demographic data showed that 40.7% of the young people interviewed have experience in the labour market (Table). Most students are between 17-21 years old (86.9%) and were enrolled in the third cycle

(47.8%). In question 8, the students were questioned about the degree of importance given to Health and Work Safety (Table 2). As question 8 was composed of different amounts of subjects (which varied due to the cluster, that is, different courses had different options for course units), data normalization was necessary. For this, a six-point scale was created (Highest importance, High importance, Moderate importance, Low importance, Very low importance and Absolute no important) and from then on, the respective intervals were defined.

Table 2 – Grade of importance by cluster

Cluster	Grade of importance
C1	Low importance
C2	Moderate importance
C3	Moderate importance
C4	Moderate importance
C5	Moderate importance
C6	Moderate importance
C7	Very low importance
C8	Highest importance
C9	Moderate importance
C10	Highest importance

Question 10 asked the students about the importance given to Work Safety. In this question, a scale from 0 to 10 was used, where 0 means “Not important” and 10 means “Extremely important”. The overall average was 8.78 (Table 1), where most students attach moderate importance to the topic (Figure 3).

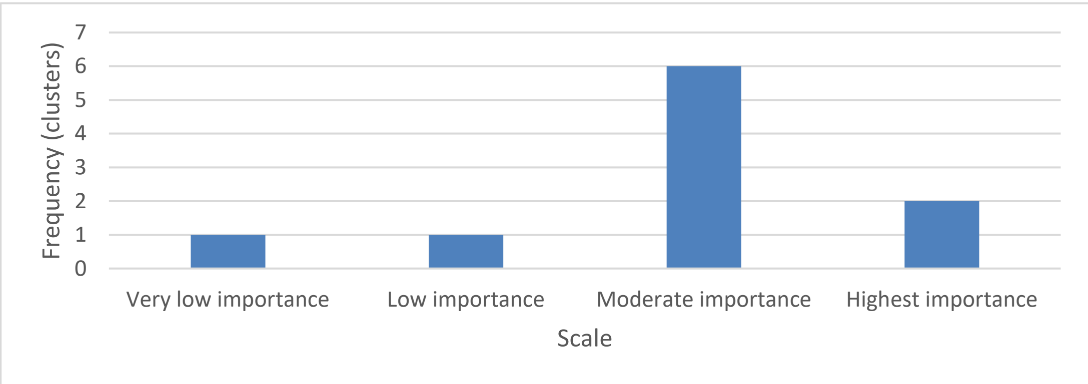

Figure 3 – Histogram of the importance given to Work Safety.

When asked whether worker safety issues should be more rigid due to the COVID 19 pandemic (Q14), 98.9% of students stated that safety measures should be firmer (Table 3).

Table 3 - Safety issues more rigid during a pandemic

Cluster	Yes	No
1	n=43 (100%)	n=0 %
2	n=32 (100%)	n=0 %
3	n=21 (100%)	n=0 %
4	n=68 (97,1%)	n=2 (2,9%)
5	n=5 (100%)	n=0 %
6	n=12 (100%)	n=0 %
7	n=25 (100%)	n=0 %
8	n=4 (100%)	n=0 %
9	n=31 (100%)	n=0 %
10	n=31 (96,9%)	n=1 (3,1%)

Question 15 asked the students if, since the emergence of the current pandemic, they attributed more, less, or equal importance to the theme of Safety and Health at Work (Table 4). 83.6% of students attach more importance to Safety and Health at Work in times of pandemic. Most students attach "Most Important" to the topic (Figure 4).

Table 4 - Level of importance attached to safety in the context of the pandemic.

Cluster	Most Important	Equal Important	Least Important
1	n=36 (83,7 %)	n=7 (16,3 %)	n=0 (0 %)
2	n=31 (96,9 %)	n=1 (3,1 %)	n=0 (0 %)
3	n=16 (76,2 %)	n=5 (23,8 %)	n=0 (0 %)
4	n=56 (80 %)	n=13 (18,6 %)	n=1 (1,4 %)
5	n=5 (100 %)	n=0 (0 %)	n=0 (0 %)
6	n=10 (83,3 %)	n=2 (16,7 %)	n=0 (0 %)
7	n=22 (88 %)	n=3 (12 %)	n=0 (0 %)
8	n=3 (75 %)	n=1 (25 %)	n=0 (0 %)
9	n=26 (83,9 %)	n=5 (16,1 %)	n=0 (0 %)
10	n=25 (78,1 %)	n=7 (21,9 %)	n=0 (0 %)

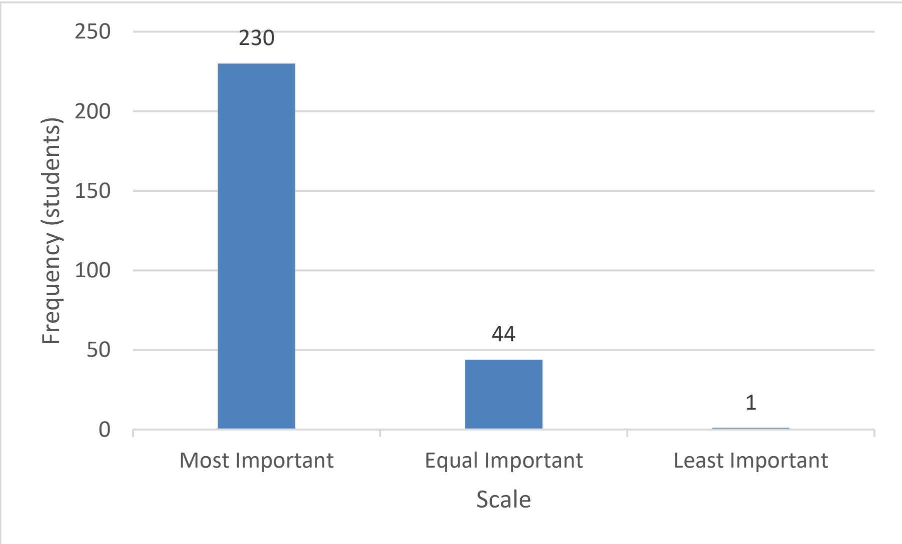

Figure 4 - The importance attached to Safety and Health at Work in times of pandemic.

4 Conclusion

This work made it possible to perceive most students have a good perception of Health and Safety at Work, which is evidenced by the responses obtained (Table). Assuming that the Portuguese educational system has a series of policies that aim to ensure the learning of skills and behaviours related to Health, Safety and Environment, which must be worked on during basic and secondary education (Anacleto, 2020), the results collected here may - in a way - be a reflection of this effort. Thus, since the study of the organizational climate is used to identify what are the behaviours supported by the organization/institution (Zohar, 2010), it is concluded that in the case of UM, the students participating in this work have a positive safety climate. This conclusion is in line with the results obtained in Anacleto (2020), which assessed the safety culture of students at that university. However, even as a positive result, there is always room for improvement. The disparities between courses must be reduced to level the perception concerning Occupational Health and Safety.

The limitations of this work include (A) the desired sample size that has not been reached (N = 343) and (B) the study focused only on the students' perception of Health and Safety at Work, leaving aside the Preferences and Knowledge categories.

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Online adaptation strategies for active learning methodologies in STEM education

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Abstract

Due to Covid-19 pandemic, adaptations for carrying out remote work have become necessary in various sectors of society. Among these, the educational area was one of the most impacted and, with the goal of creating a "new normal", activities that used to be face-to-face are now performed online. Considering the importance of society-university integration, the university outreach programs, which form one of the pillars of the public university, also had to be adapted so the activities would continue. This paper presents the planning and execution strategies adopted by the Fast Girls outreach project team. This project is an initiative of the Faculty of Technology in partnership with other units of the University of Brasília and has the purpose of motivating girls and young women, students of basic public education from the outskirts of Brasília to pursue careers in the STEM areas (Science, Technology, Engineering and Mathematics). In this process, active teaching-learning strategies based on pedagogical workshops with hands-on activities, games, interactive lectures, women's testimonials, and conversation rounds were used. Meanwhile the difficulties encountered, as well as the results achieved were identified and discussed, highlighting the enriching character of these procedures for the undergraduate students in terms of their ability to adapt to the execution of the teaching-learning methods in face of the new reality. In this conception, the work presents positive results, extending the benefits of the use of active learning strategies beyond basic education, reaching undergraduate students, even in times of distance education.

Keywords: Active Learning; STEM Education; Online Workshops; Distance Education.

1 Introduction

University extension is one of the three pillars of public university, whose main role is to establish continuous communication between the internal and external community. Through it, the academic community has the opportunity, by sharing knowledge, to contribute to the solution of social problems, to reduce inequalities and promote development. Along these lines, the research and extension project "Fast Girls" from the University of Brasilia has existed for 8 years and its main objective is to promote gender equity in the exact courses, most specifically, in the engineering courses. The project was born due to the low number of women in the areas of exact sciences and technologies, which, according to Andréa Barreto (2014), reaches only about 32%. The actions aim to encourage public education students to pursue a career in the areas of Science, Technology, Engineering and Mathematics (STEM) through active learning methodologies, as well as strategies that encourage reflection on the role of women in society and the factors that influence their choices.

The project in its usual format has been conquering the public of basic education and collecting, together with the schools involved, achievements reflected both in the contentment of the members and in the number of approvals in higher education. With the pandemic, the project had to be adapted to a format that had not been foreseen, and it naturally had to face new challenges. With the new environment and new discoveries, the process of reinventing oneself, which is naturally part of the human condition, took on this context, within a fast and somewhat frightening pace, but rich in learning. It is not easy to adapt strategies which refers to active involvement to the virtual model, knowing that this result is often enabled after integration dynamics, welcoming looks and gestures that facilitate the feeling of belonging to the new group.

Active learning methods and strategies are the foundation of the Fast Girls project and they mean "anything course-related that all students in a class session are called upon to do other than simply watching, listening and taking notes." (Felder & Brent, 2009, p. 2). Activities such as games, debates, projects, and experiments tend to instigate students and help them during their learning process. Dismissing this way of working would be to radically alter the proposal that had already demonstrated its success. Thus, we decided to adapt STEM actions to the new virtual environment, and this required the team to exercise creativity and critical thinking, important educational skills in the 21st century, according to the OECD[2] (Ananiadou, K. and M. Claro, 2009).

Such active learning methodologies, as stated, aim at using different strategies and activities to go beyond traditional classes. Therefore, games, debates, experiments, and project development are used to instigate and help students to become protagonists of their own learning (Ziegelmeier & Topaz, 2015). In traditional classes, the teacher usually transmits information through content classes, which generally follow a somewhat predetermined method: lecture, exercises and assessment. However, such a method tends to generate more distractions, since the student does not have the chance to exercise other skills than only attend the class, and this model can be discouraging because it does not bring real motivation to the students (Prince & Felder, 2006). Therefore, to mitigate such difficulties, the main learning methodologies used in the Fast Girls project consist of the flipped classroom and hands-on experiences.

The flipped classroom, in general terms, consists of presenting the student with videos, texts, games and anything regarding the content that will be addressed in the classroom before it even takes place. In this type of dynamic, the student is led to gain autonomy in his studies, seeking to understand issues related to the subject before the class and, thus, maintaining the class time to clarify doubts, advance in the concepts learned and debate with colleagues (Tucker, 2012).

In addition to inverted classes, another method used refers to the practical activities that take place right after the lecture. Such methodology, called hands-on, consists of transforming all the learning acquired into manual activities, such as experiments. Hands-on activities involve several skills such as those needed to take measurements, build experiments, and analyse results (Corlu & Aydin, 2016). As a result, "learning becomes playful, realistic and pleasurable, with the potential to positively influence the interests of students pursuing a career in the fields of STEM" (Costa et al., 2020, p. 2). Experimental activities are especially important because they serve as practical examples of the theory studied and, as Srinath (2014) emphasizes, good practical examples have the ability to connect such theory with the practical applications of the subject covered. For classes in the areas of STEM, such an approach proves to be even more important, since the knowledge obtained needs to be specially consolidated and practiced with exercises (Costa et al., 2020).

In the first year of remote classes, three workshops were applied, all previously tested and evaluated in the virtual environment. Aspects such as the type of equipment used for online meetings, the eventual instability of the network and the time of remote exposure became part of the planning, as well as the use of strategies to hold the attention of girls in basic education. The workshops planning also added the logistics of providing the materials to meet the purposes of the workshops. The group's difficulty in translating the perception of its target audience should also be weighed, as one observes the participants shyness when they must express themselves in online meetings.

The present writing aims to document the adjustments made in the work form of the project Fast Girls to meet the security protocols required by COVID-19. The actions were designed to maintain the purpose of the active learning methods and strategies in the virtual environment and continue to contribute to the promotion of gender equity through activities that arouse the interest and empowerment of girls from the periphery to follow their training in areas that are not naturally designed for them. The article is divided into six topics: an introduction, the role of team in planning the activities and training the monitors, a topic detailing the

[2] Organization for Economic Cooperation and Development.

workshops applied and the strategies used, as well as an analysis of the results obtained, the conclusions and references used.

2 The role of team in planning the activities and training the monitors

Professors and undergraduate students from the Faculty of Technology and Faculty of Gama, in partnership with professors and undergraduate students in the areas of sociology, education and psychology at the University of Brasilia, formed a women team to address the issue of gender in an interdisciplinary and intersectional manner.

Among the main activities developed are the workshops, in which a topic within the scope of the subjects in the exact areas taught at the high school was approached, such as vectors, uniform rectilinear movement and Newton's Laws, electricity. Other activities, as lectures, always took place with a successful female personality, such as researchers, engineers and even sport personalities like Maiara Basso, a young Brazilian motocross champion. In these spaces, students had the opportunity to meet and talk to women of outstanding professional importance. In many events and meetings promoted, there are conversation circles to discuss gender, race, and social class issues, so that the students have space to express their opinions and thoughts. Generally, a film or documentary is presented and, based on what is seen, a space is then opened for discussion and exchange of ideas.

To enable the execution of these activities, at the beginning of each semester, a planning meeting is held with all members of the project team and a calendar of activities is drawn up for the respective school cycle, with proposals for activities and the people responsible for carrying them out.

As new workshops are conceived, other meetings are held with the team to verify and discuss the feasibility of each proposed theme. After the theme is approved, one of the professors is responsible for supervising the development of the workshop, having the role of guiding the monitors during the elaboration process. The professor accompanies all the planning stages of the workshop, suggesting ways to approach the content using active learning methods and strategies, and helping in the adjustments of the activity.

The ones responsible for running the workshops are undergraduate students from various STEM fields. When they join the project, these students undergo a training process, whose main purpose is to make them capable of acting as monitors. The above-mentioned process is divided into three stages. In the first moment, after joining the project, the students assume the role of observers, participating in meetings and workshops, and being able to clarify their doubts about the extension action.

In a second moment, the new members start helping in workshops organized by the more experienced monitors, giving assistance during the elaboration of the contents and contributing with new ideas. And, finally, in the third moment, the new monitor is responsible for creating a new workshop and putting it into practice, working together with the other project participants, as well as with the mentors, professors from the University of Brasilia.

3 Face-to-face and remote workshops: What is different?

The performance of the Fast Girls project, from the beginning of its activity in 2013, until the beginning of 2020, took place exclusively face to face. In this perspective, the process of planning and conducting workshops did not consider factors such as electronic resources availability by students, given that there was no need to supply the lack of contact between the participants through digital resources. Thus, until then, the team's main concern was to apply the active learning strategies to maximize the educational and personal experience built during the proposed activities.

Due to the COVID-19 pandemic, however, and the consequent social distance caused by the health crisis, the project had to face an unusual scenario. So, despite the difficulties identified, intending to fulfil its objectives, within which to encourage the engagement of students from the public school system in the Federal District with the STEM areas, as well as allowing the exchange of experiences between the participants, the project began to carry on its role remotely only for the first time.

In relation to the different realities of internet access and the technological apparatus resources, workshops that could be carried out in the students' homes were carefully thought and planned, and the strategies already mentioned were used to motivate them. We set up workshops that used interactive tools, such as online games, and experiments that were easy to be reproduced, without posing any danger to students. Sending material kits enabled the continuity of activities. Also, it is possible to notice that without the material kits the activities would be focused on the theoretical scope, moving away from the idealization of the project, since in STEM classes, theory and practice should always be complementary (Srinath, 2014). It was also necessary for both parties to adapt to the use of virtual platforms to teach the classes.

That said, difficulties were naturally encountered, which did not prevent, however, the conduction of works in 2020, among which, we may point out the first three workshops planned and run by the team in the STEM area. The first was related the theme of vectors and their operations, while the last two referred to electricity, including the hands-on method, already used and highly valued in face-to-face workshops. We would also like to emphasize the essential role of the debates and lectures within the project. A transposition of this segment of activity was also planned in the remote modality, with all proposals proving to be successful.

In view of the success achieved, the following texts discuss how the works of the Fast Girls project were conceived and practiced before social distancing, as well as the practices adopted during the pandemic. Finally, the main difficulties encountered by the monitors during this transition are pointed out.

3.1 Face-to-face workshops

As explained so far, since 2013, the beginning of the Fast Girls project, it had been conducted face-to-face, through the promotion of workshops, lectures, or monthly meetings with the students. These contacts were always on Fridays, the day of the week reserved for their activities, and hosted at the University of Brasília or at the “Centro de Ensino Médio 404” in Santa Maria, the school the students attended, depending on the resources needed to carry out the activities.

The face-to-face workshops had 3 moments. Initially, an interactive class was held, when the project monitors not only presented the content, but also the students participated collaboratively during the explanations. The practical part of the workshop was developed with an aim at fixing the content covered in the presentation and showing how the concepts displayed were observed on a daily basis, thus enabling students to apply what they had previously learned. The third moment was for discussions and reflections about learning.

An example of this type of practice is the vector workshop. In it, a map of the University was given to students, who needed to use the vector properties presented by the monitors to find clues hidden on campus and, with each new clue, a puzzle had to be solved. The Time and Movement workshop, on the other hand, allowed students to apply the concepts of average speed and uniform rectilinear motion in remote control carts. In this dynamic, the students needed to go through automobile circuits with their carts, note the distance traveled, as well as the time spent to finish the route. Thus, through these interactive activities, students were able to observe in practice how physics, mathematics, and chemistry act in their daily lives.

3.2 Remote workshops

3.2.1 Vector workshop: the first workshop held online

The first workshop held during remote education had as an object of interest vectors and their mathematical operations, a similar proposal to the workshop held face-to-face, also on the same topic. The activity was planned to be applied in two meetings, both on Fridays. At first, the monitors responsible for the activities met so that the main ideas regarding the transposition of the activity to remote education were discussed. It was considered a good idea to develop a game on the theme, considering that, when well designed, it increases participation and interaction among students, favouring those who have difficulty assimilating the content through traditional methods. Therefore, with the objective of continuing to hold the workshops in such a way that the students were able to successfully learn the presented content, a small booklet was developed before each meeting. It had a light and relaxed look, containing information that would be worked, so that students could get ahead in the search for knowledge, the so-called flipped classroom. For this purpose, images, animated videos, and manual activities were used, such as mental maps, organized to provide familiarization with the theme and interest in active participation. Thus, the idealization of the flipped classroom, as well as interactive slides, maps, cards containing challenges and a puzzle, were resources designed to improve problem-solving skills.

After delimiting the topics covered in the activity, the group decided, for playful purposes, to set the activity in the Harry Potter universe, since it is a well-appreciated series by the target audience. During the elaboration of the maps used in the dynamics, the Geogebra software was used as a support. Once the maps were created, they were hosted together with the game tracks on the Quizlet platform. Given the need to create more interactive and visually attractive slide presentations, PowerPoint was use as well.

After developing the game, as well as the lesson support material, texts and videos related to the topic of vectors were organized so that the participants could become familiar with the subject, in order to provide greater engagement on the day of the activity. The difficulties encountered were mainly related to the distribution and management of tasks, given the small number of monitors involved in the elaboration and execution of the activity, as well as the search for virtual tools, such as software that met the demands that arose, while they were of course, accessible to all participants. In this sense, the extended time spent in planning and surveying material is interpreted as natural, with the consequent impact of a greater number of tests among the team.

At the end of the activity, it was observed that, although successful and well accepted among the target audience, the game needed modifications so that better gameplay was achieved. The vulnerabilities found were mainly reflected in the execution time. Due to the high number of topics raised on vectors and their operations, the theoretical presentation lasted an average of one and a half hour, requiring constant revision, since one of the objectives of the game was to perform calculations. As for the level of difficulty of the issues raised, in specific points they went beyond what is usually included during high school, constituting, therefore, one of the flaws identified by the team. Regarding the reception of students at the workshop, students' feedback was considered positive. However, participation and involvement with the texts and videos previously provided through the flipped classroom was markedly low, which resulted in losses to the interaction among group members. Such occurrence was observed especially in the first meeting, which aimed not only to explain the main points of the theoretical content, but also to acclimatize the students to the platforms that would be used.

3.2.2 Workshop on batteries and cards: activities related to electricity

Following the vector workshop, two activities specific to the STEM areas were planned and carried out in 2020, both related to electricity, with the common characteristic of adopting the hands-on methodology, an approach previously used face-to-face and of notorious importance within the Fast Girls project.

The first workshop carried out within the context of electrical charges in flux consisted of the production of a galvanic cell, a device capable of generating electrical energy from a chemical reaction, thus dealing with the content of electrochemistry. Its unfolding, thus, culminated in an experimental activity that used as a teaching-learning method the investigation of phenomena. In addition to the usual slide shows and flipped classroom, materials were provided to students - among which were copper coins, galvanized washers, and an LED, which made it possible to carry out the experiment through a videoconference with the monitors who set up a copper-zinc battery, therefore turning on an LED through an oxidation reaction. As it is a content with a high degree of abstraction, since it alludes to the subatomic universe, a simulation platform was used to illustrate the experiment known as the Daniel battery to stimulate the students' curiosity before the beginning of the theoretical exposition, resulting in a better understanding of the activity proposed. Due to the low adherence to the theoretical material separated for the vector workshop, a gymkhana was organized, where the activities were individually carried out before and during the workshop, activities based on the texts and videos presented in the flipped classroom. The student with most points at the end of the activity was rewarded with a prize. In this sense, the participants answered a questionnaire on the topics covered in the previously sent document, when they were instructed to do a research on how the subject of electrochemistry is related to the phenomena observed in daily life.

In turn, the second workshop of this thematic group focused on electrical circuits, in which the elaboration of decorated cards was used as a didactic tool. Using LEDs, conductive tape and 3V battery, an electrical circuit was set up on paper; the responsible monitors guided the students throughout the process in a videoconference during the workshop. Searching for greater simplicity, part of the materials provided consisted of papers and decorative items, so the participants were able to decorate the card according to their individual preferences, resulting in a wide variety of prints and showing a relaxed atmosphere when exhibiting the final products from the activity. Due to the complexity of the content covered, the elaboration of mind maps was suggested. They are information management diagrams that allow a broader view and faster understanding of the subject. During this workshop, the use of the Mentimeter was also introduced, a tool that allowed the application of a questionnaire during the presentation with feedback in real time. It enabled the group to identify with precision and agility the students 'vulnerabilities in theoretical terms.

Regarding the planning and execution of activities, the monitors, undergraduate students, prepared the lesson plan, experiments and other activities taught, though project administrators were the ones responsible for the purchase and distribution of materials.

As these were experimental activities, the main challenges were related to the tests performed, given the distance between the monitors and the consequent difficulty in replicating them with alternative materials. The execution, however, took place smoothly, so that the technical objectives initially proposed, such as greater engagement and collaboration of the participants during the theoretical explanation, were fully achieved.

4 Tools for evaluation and analysis of results

In this section it will be present qualitative results based on the views of the monitors and the undergraduate students about the workshops held. To this end, a questionnaire was prepared for the monitors and also a questionnaire for each workshop held, with the objective of obtaining feedback from the high school students in order to improve the activities and overcome the difficulties encountered.

A total of 7 monitors, undergraduate students from the exact area answered the questionnaire intended for them. The group of high school students participating in the project in 2020 consisted of 14 girls aged 15 to 17. Four students answered the questionnaires for the electric circuits workshop and 13 students answered the questionnaires for the batteries workshop.

In the form sent to the high school students there were questions regarding the performance of the workshop, the content taught, the clarity of the explanations, the topics that should have been explored more, space for praise and criticism.

In addition, to complement the information obtained in the monitors' questionnaire, it was also conducted an interview with the project monitors, who reported that one of the main problems encountered during the adaptation to the new context was the demand for the development of workshops that had the same quality and interactivity as before. The interview took place in early April 2021.

4.1 Monitor's view

From the analysis of the questionnaires sent to the monitors it was found that around 71.4% of the monitors had not had contact with remote education previously, which required greater dedication in elaborating solutions for a little experienced environment.

Among the problems identified in the elaboration of solutions, there was the interaction difficulty between the monitors and students, the difficulty of internet and electronic devices access and doubts about the type of workshop that could be offered, being the adaptation of a face-to-face workshop to a remote one, the most challenging of all measures.

Replacing face-to-face workshops with remote ones brought problems related to the elaboration of these practices, and to how the contents previously given in the classroom would be approached. As a result, its development became more time-consuming and challenging, since it was necessary to assess problems that could occur - such as the failure of the software to be used and the difficulty of students accessing the programs

- in addition to the need to think of a model class that involved the participants, resulting in, among other aspects, the overload of those responsible for the activities. The monitor´s level of encouragement in giving workshops was questioned. That ranged from 1 to 5, in which 1 was seen as the worst level of motivation and 5 the most satisfactory and it was observed that most of the monitors preferred the face-to-face teaching model, as the data collected in the interview show that 57% of the monitors chose to score 5, when referring to doing the face-to-face activities, while, at a remote level, only 14% of the interviewees opted for this alternative.

In relation to the time spent in the elaboration of the workshops, it was observed that over time the monitors became more agile, since they gradually gained experience with this class model, with the problems that could arise in the workshops and, therefore, the period of elaboration of activities was shortened.

Interaction difficulty between monitors and students was also a potential generator of problems, as it could cause greater demotivation of monitors executing the workshops.

In view of the new requirements, it was observed that the tutors acquired and developed multiple skills in the face of the challenges encountered, such as: the development of more suited classes to the profile of students (adapted to be both expository and practical), creativity , imagination, teamwork (since the workshops were designed by a group of monitors), organization, logical reasoning, critical thinking, the ability to solve problems, as well as greater flexibility and mastery of virtual resources, for example.

4.2 High school student´s view

After analysing the questionnaires sent to the high school students, we were able to obtain a general feedback of the workshops, as well as opinions and criticisms. Thirteen students answered the battery workshop questionnaire, nine of whom had never studied galvanic cells, and four students answered the electric circuits workshop questionnaire.

At the end of the workshops and after analysing the forms sent to the students, it was observed that the strategies adopted during the execution of the activities reached the expected goals of motivating the students with a new way of presenting and working with contents.

Regarding the use of colorful and fun slides during the class, all thirteen respondents approved the quality of the presentation. The interactive theoretical presentation of the battery workshop lasted less than an hour and all students agreed that the subjects covered, galvanic cells, electrolytic cells, ox reduction reactions, batteries, and electric current were adequate for the proposed experiment. The time was also considered adequate for them to learn without getting too tired. For the electric circuits workshop all students also considered the time adequate.

Most of the students reported that they felt more motivated by the hands-on activities, with the experiments performed in the battery and electrical circuit workshops. Regarding theory and the concepts taught, all reports indicated that these contributed to the understanding of the practical part of the workshop. In this sense, comments such as "I was very excited to make a battery" and "it generated more interest in the content taught in the slides" were some of the messages received, and it can be concluded that the theoretical and practical teachings complemented each other.

The hands-on discovery of how simple objects from our everyday life work, be it a battery or an electric circuit, and the sharing of this experience on social networks has maintained the students' interest in STEM subjects even after the end of the workshops. All of the students reported that the most interesting part of the workshop was related to the hands-on, and some of them pointed out that they would like all the activities to keep this format, thus confirming the potential of hands-on activities to motivate students' learning even when the activities are done remotely.

The adoption of the flipped classroom aims to reduce the content presentation time, and the competition in the form of a gymkhana held in the battery workshop proved to be an effective engagement tool. Twelve of the thirteen students present on the day of the synchronous activity viewed the material previously sent. This strategy was adopted because, in the previous workshop on vectors, we noticed a lack of interest from the students in accessing the contents previously. The use of alternative engagement strategies, such as games and competitions may be interesting for this purpose.

5 Conclusion

Considering what was exposed in this article, we may conclude that even in a totally new and sudden scenario for all, active learning strategies proved to be effective for remote teaching. Despite the difficulties and obstacles encountered along the way, we were able to conclude the project´s main objective during the Covid-19 pandemic: to continue the project so that the workshops would remain with quality and attractiveness.

It appears that active learning strategies are a good alternative to ensure that the student remains focused for almost the entire class, since, unlike traditional teaching methods, the student is encouraged to establish communication with the monitor. Strategies such as flipped classroom and hands-on activities have been shown to be effective regarding a dynamic class, and efficient in terms of learning, involving the student before, during and after the workshop. Such strategies proved to be ideal to close the gap between monitors and students, in addition to reducing the lack of motivation to workshops attendance.

Therefore, due to the good results obtained, the project will continue to be based on active learning strategies aimed at remote education throughout the period that social isolation endures, in an attempt to bring to online workshops, the proximity and interaction previously adopted in presential encounters, in addition to enabling higher interest in learning.

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A Problem-based Learning Experience in Engineering Education

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Abstract

This paper reports a Problem Based Learning (PBL) experience, held in the Basic Chemistry and Experimental course of the Engineering programs at the University of Caxias do Sul, involving problems related to chemical reactions that occur in daily life. The experiment was structured according to the "Seven Steps of PBL Implementation". The data were collected using two instruments, a pre-test and a post-test on topics of interest with the objective of evaluating students' learning through the PBL method, and an instrument that consisted of an open question in which students were asked to describe the main characteristics of their classes with the Traditional Teaching Model and the characteristics of the classes that used the PBL method. The results of the pre and post-test show the contribution of PBL to the occurrence of a conceptual evolution on chemical reactions. As for the verbalizations about the characteristics of the Traditional Teaching Model and the PBL, the results show that students understand the disadvantages of teaching in the traditional model and the advantages of learning in an environment conceived through the foundations of PBL. The statements show that PBL favours the development of complex skills such as questioning and teamwork, and that decision-making and research are present in the process of learning with PBL. Through these results, it is evident the improvement in the conceptual, procedural and attitudinal learning of the students who participated in the classes with the PBL method in function of better grades and in the development of more complex skills. We know that adequate professional performance goes far beyond quantitative results and student perceptions. However, these results are encouraging to continue new studies. The experience described and analysed was developed in only one course, but, as in other studies, indicated that PBL is an active learning method that is conducive to the occurrence of a meaningful learning in Engineering Education.

Keywords: Problem Based Learning; Active Learning; Engineering Education; Chemical Reactions.

1 Introduction

In many higher education institutions, the concept of teaching is still synonymous of the presentation of content. In these institutions, teacher's action is centered on offering expository lectures, and students' action on listening to these presentations to accumulate information. These teaching and learning processes generate predominantly mechanical (rote) learning on the part of students. In this context, we look at Engineering undergraduate programs and we see that teaching strategies and methods also need to be adapted to the new globalized reality, because if there is no innovation in teaching and learning processes, hardly, the new professional will dare to innovate in the work environment. In this scenario, it is important to base studies and actions to favor the change of the epistemological and pedagogical model of the teacher. Teachers' and students' conception of teaching and learning, teachers' and students' roles, require in the current scenario a process that creates conditions for the occurrence of lasting learning, establishing relationships between new knowledge and what is already known. Thus, teaching is more than passing information. Teaching is to encourage the student to think, to interpret information and, with that, to produce ways of solving problem situations, interacting with colleagues, analyzing demands, proposing actions, and making decisions.

According to the United Nations Educational, Scientific and Cultural Organization (UNESCO), the main asset of an organization resides in the quality of its human capital (UNESCO, 1998). By analogy, in higher education institutions, the quality of their faculty must pass through epistemological and pedagogical training, as it is through it that the proposals of the program's pedagogical projects are designed. The Law of Guidelines and Bases (Brazil, 1999) for Engineering programs, as well as INOVA Engineering (INOVA, 2006), proposes that its graduates be able to conceive, design, analyze systems, products and processes; plan, supervise, conduct experiments, interpret results, work in multidisciplinary teams, communicate efficiently, assess the economic viability of projects and the impact of engineering activities in the social and environmental context. Given these needs, what teaching strategies and methods have the potential to develop these skills? What aspects of mediation need to be present in learning environments when the focus is on more lasting learning?

Learning environments, which favor such training profile, are characterized in spaces where teachers and students work together to develop skills. Creating conditions through a sequence of activities that aim to train the engineer as a creative and innovative professional, and that can transpose and develop new knowledge to deal appropriately with reality is essential. Teaching and learning processes, consistent with this trend, need to be increasingly focused on students' actions with situations that favor interaction, collaboration, exchange of knowledge and the development of meaningful learning (Ausubel, 2003).

Learning environments conceived using the Problem Based Learning (PBL) method can be an alternative for the teacher who believes that it is necessary to break with the traditional teaching model where the student learns by listening and the teacher teaches by talking. PBL is an active learning method, centered on the student, which aims to get him to learn about the subject in the context of real, complex and multifaceted problems (Graaff & Kolmos, 2007). According to Chen, Kolmos & Du (2021), during the last 40 years, problem- and project-based learning (PBL) has been widely adopted in Engineering Education because of its expected effectiveness in developing students' professional knowledge and transferable skills.

Working as a team, students can identify what they already know, what they need to know and how and where to access the new information needed to solve the problem. The teacher's role is to facilitate learning, providing appropriate conditions for the process, doing a prior knowledge survey, providing the appropriate resources, and conducting class discussions, as well as planning student assessments. PBL differs from conventional educational methods especially because it has as its main objective the meaningful learning of the student who is an active subject in this process. Its purpose is to enhance the development of essential skills for the success of the future professional (Booth, Sauer & Villas-Boas, 2016). In 21st century work environments, success requires more than knowledge and basic skills. With PBL, students not only understand content more deeply, but also learn to take responsibility, build trust, solve problems, work collaboratively, communicate ideas, be innovative and creative (Savin-Baden & Howell- Major, 2004).

This paper reports a PBL experience carried out in the Basic and Experimental Chemistry course of the Engineering programs at the University of Caxias do Sul (UCS), in the state of Rio Grande do Sul, Brazil, involving problems related to chemical reactions that occur in everyday life. The following topics are presented in this article: the teaching and learning context in which the experience was developed, the methodology for implementing the PBL method, the results and some final considerations.

2 The Teaching and Learning Context

Working with problematic situations has always been part of the activities of a group of teachers in the area of Exact Sciences and Engineering at UCS. However, more precisely in the period from 2010 to 2014, this group of teachers started the development of a project entitled "UCS-PROMOPETRO: New Challenges for the Engineer of the Future (PETROFUT)" with financial support from FINEP, whose main purpose was to strengthen teaching science and awakening interest in young people for careers in the STEM area (Villas-Boas et al, 2016). In the development of the activities of this project, the method used was Problem Based Learning (PBL), in order to contemplate activities that established connections between the basic knowledge of the Exact and Natural Sciences at high school level and practical applications of the technological areas that had as objective the solution of real problems in the scope of engineering services and industrial activities, including those focused on environmental issues. To this end, the group of teachers studied all aspects of PBL for six months and developed workshops based on this method. This experience and a faculty training in Project-based Learning carried out at UCS in 2012 by specialists from the University of Minho were fundamental for PBL to become part of the planning of some courses of UCS Engineering programs.

UCS Exact Sciences and Engineering area offers 12 Engineering courses (Environmental, Automotive, Civil, Food, Computer, Control and Automation, Materials, Production, Electrical, Mechanics and Chemistry) and has over 3000 students. Most of these students are part-time students and work in the industries in the region. Since they are already employed, many of them are just looking for an Engineering degree.

Combined with this, a significant number of UCS students did not have a good background in Science and Mathematics in high school, which leads them to perform poorly in basic subjects and, consequently, leads many of them to drop out of the program. In this context, the use of an active learning method in the Basic and Experimental Chemistry course was presented as an alternative that could bring many positive results for the learning of these students, including influencing the change in their study habits.

This work was developed with a group of the Basic and Experimental Chemistry course within the Engineering programs at UCS during the first semester of the year 2016. This course is part of the set of courses of the second semester of the Engineering programs. The group, named class A, was composed of twenty-four students, aged 19 to 22 years. Class A students experienced the development of concepts about chemical reactions through the application of the PBL method.

The application of PBL involved problems related to chemical reactions that occur in daily life, with an emphasis on chemical reactions between corrosive media and different materials and was developed in 10 meetings in the first semester of 2016. The semester had 21 meetings of 4 hours of class.

Class A students were divided into teams of 4 students where they took on different roles (leader, secretary and team members). In addition to the course's teacher, a Physics teacher and a master's student in the Graduate Program in Science and Mathematics Teaching, in the field of Biology, also acted as tutors.

3 Method Implementation

Considering the many advantages of using PBL in Engineering courses and programs, notably favoring the integration of knowledge, autonomous learning, collaborative learning, among others, the teacher of the Basic and Experimental Chemistry course, opted for the implementation of PBL, with the objective of to motivate, mainly, students of Engineering programs who do not understand the importance of studying Chemistry. In this context, the teacher identified the conceptual and procedural contents to be developed in a learning environment designed using PBL.

3.1 The development steps of the PBL experience

The experience was structured, inspired by the "Seven Steps to PBL" (Albanese & Mitchell, 1993; Barrows & Tamblyn, 1980; Boud & Feletti, 1997), and was applied to class A in the sequence presented below:

Step 1: students examined damaged metal structures, which led them to manifest their prior knowledge. Then, a pre-test on everyday chemical reactions was applied. This step helped in the identification of previous knowledge, accepted or not accepted in the context of the course subjects.

Step 2: a problem was presented to the students, and it was related to a complex real-world problem in order to mobilize students about new knowledge. The problem situation presented is set out below:

Itaipu Binacional Power Plant (https://www.itaipu.gov.br/en) has 20 hydrogenerators with individual rated power of 700 MW. Each hydrogenerator has 37 heat exchangers, 16 of which are air / water exchangers from the stator core. The first evidence of water leakage in one of the hydrogenerators occurred in 1992, on machine 4, followed by another leak in 1993, on machine 15, and the problem is no longer considered an isolated case. In this context, as a team, you must prepare an intervention proposal to avoid future spills in the hydroelectric generators of the Itaipu Binacional Power Plant. The proposal must present actions based on the areas of Physics, Chemistry and Biology, considering the social and environmental contexts.

The students, gathered in teams of 4 components, through discussion, raised questions, identified gaps in knowledge existing in the team and characteristics of the problem that they did not understand.

Step 3: students prioritize learning issues and afterwards planned a work schedule with individual and collective actions to clarify issues of the problem to be investigated.

Step 4: students individually searched answers for the questions to be investigated and the concepts related to their knowledge gaps.

Step 5: students, gathered as a team, explored the questions chosen for studies in order to integrate new knowledge into the real context of the problem. At the end of this step, other relevant issues and aspects of the phenomenon under study were taken up, for the systematization of knowledge supported by the reading of a scientific article, followed by a collaborative activity in teams.

Step 6: students, gathered in teams, presented their solutions to the problem for the large group.

Step 7: students assessed the feasibility of using PBL through two data collection instruments.

3.2 About the pre-tests and the post-tests

Pre- and post-tests were used to validate the knowledge built by students in the course. The pre-test consisted of a set of 10 open questions applied to students in class A, to assess the level of knowledge about the subjects that would be taught. It was also explained that the purpose of the pre and post-test was to assess the knowledge built. In addition, the results of the pre- and post-test comparison aimed to answer the following question: "Did the students achieve the learning outcomes?"

The test questions were developed in line with the objectives of the classes. This criterion ensured visibility to provide evidence and to demonstrate what knowledge students have developed with PBL. The choice for open-ended questions was because they require participants to use their own words to answer or comment on a specific situation. The questions were developed with simple words, without ambiguity and according to the learning outcomes.

The pre and post-test lasted 40 minutes each. The tests were carried out individually, to obtain a more real analysis on the conceptions of each student. The application interval for these instruments was six weeks. During that time, the steps of the PBL described above were developed. The post-test contained the same open questions as the pre-test. A definite criterion was that the pre-test questions were not discussed at the following meetings, nor were any comments made on their resolution.

The analysis performed in the pre and post-test was a quantitative analysis. The distribution of students' grades in each question, both in the pre and post-tests, was verified to assess the learning that occurred. The investigation of the occurrence of conceptual evolution was done through an analysis of the students' answers to the set of open questions.

4 Results

In this section, we will present the results of the pre- and post-tests and some testimonies from students in class A about the teaching-learning method adopted. Believing in the potential of PBL for the acquisition of meaningful knowledge and in the occurrence of a meaningful learning of concepts related to chemical reactions, this investigation sought to highlight possibilities or limitations in the use of the method used.

4.1 Results of the pre-tests and the post-tests

Figure 1 shows the distribution of grades of students in class A, submitted to the pre-test and the post-test. It can be seen in Figure 1 that 70% of the students in class A submitted to the pre-test scored between 1.0 and 4.0 on a scale from 0 to 10.0. Still in Figure 1, it can be seen that 80% of students in class A submitted to the post-test obtained scores between 5.1 and 8.0. The results presented in Figure 1 show the contribution of PBL in the occurrence of conceptual evolution.

Through these results it is evident the improvement in the learning of the students who participated in the classes with the PBL method considering the better grades. We know that academic success goes far beyond the quantitative results obtained in this study, however, these results are encouraging to continue with new studies. As mentioned before, with PBL, students develop important skills as group work, autonomous learning, self-assessment skills, time planning, project work or oral and written expression skills. PBL also improves student motivation, which translates into better academic performance and greater persistence in the study.

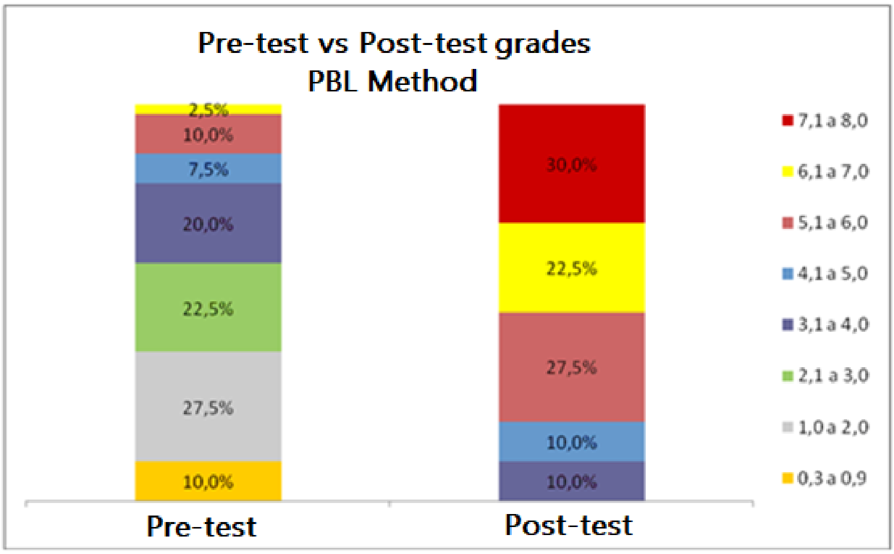

Figure 1. Distribution of Pre-test vs Post-tests grades of students in class A.

4.2 Testimonials from Class A students about their experience with PBL

Class A teams were named E1, E2, E3, E4, E5 and E6. Most student teams evaluated the PBL proposal positively. Highlighted some verbalizations of students from teams E2, E3, E4 and E6.

The students of the E2 team pointed out that "this strategy made the meetings active, the work of one colleague complemented the work of the other, with the exception of a colleague who was very slow". They also stressed that "we learned to research in reliable sources and to present the productions with less nervousness".

The students of the E3 team pointed out that "learning was built through the collaboration of everyone, with many discussions, help from colleagues and organization of the team. The team was advancing in the records and in the communication during the process".

The students of the E4 team stressed that "we were very involved in the activities, so the class was not monotonous, it did not make us sleep", and that "we also study in the classroom itself and demanded the tasks of colleagues and also helped some colleagues".

The students of the E6 team described that this method "... favored the ability to know different sources of information about the necessary concepts, and during discussions in the team we better understand these concepts to apply them in the problem situation". They also stressed that "two colleagues were hardly involved in the activities, but the others were committed to the team, which allowed for a good interaction for the development of professional skills and the understanding of concepts".

The students from teams E1 and E5 highlighted that "... we had a lot of difficulties in this process ...." ... the main difficulties were the lack of initiative and of a ''head to pilot the activities (leader), difficulties in plan work, make decisions, because one waited for the other"...

The students of the E5 team also pointed out that "contact with other teams was especially important for us, gave us more disposition, initiative", and commented among themselves that "... if the other teams were doing it, we will be able to do it too" and so "The process was happening in the team with more guidance from the teacher and tutors".

In this context, it is possible to affirm that the PBL method was well accepted by most students in class A, and that PBL favored the development of skills for: working in teams, researching, problematizing, planning, deciding, recording data, systematizing information, analyzing, synthesizing, building arguments and for the development of oral and written communication.

4.3 Students comparing PBL with the Traditional Teaching Model

Students were asked to evaluate the main characteristics of the two different methods (Traditional Teaching Model and classes that used the PBL method) and their potential to promote learning and the development of skills and attitudes. The tabulation of the verbalizations of students in Class A is shown in Table 1 below. From the verbalizations presented in Table 1, it can be seen that the students presented opinions that were quite consistent with the characteristics of each of the teaching methods. These results indicate that students understand the disadvantages of teaching in the Traditional Teaching Model and the advantages of learning in an environment designed using PBL, where they must assume responsibilities, build trust, solve problems, work collaboratively, communicate ideas, to be innovative and creative, and to work in teams.

Table 1. Student verbalizations about the characteristics of classes in the Traditional Teaching Model and of classes with the PBL method.

Classes in the Traditional Model	Classes with the PBL method	
Predominance of teachers' speech (15)	Activity is motivating, it is related to a real situation (24)	Information search (24)
Student work is individual (11)	Work related to future professional practice (17)	Decision making (20)
The study is with a book or handout (13)	Need to adapt to group work and to manage time (12)	Selection and outline of reliable information sources (24)
The activity in the classes is listening, copying, looking at slides (15)	Need to adapt to group work and to manage time (12)	Planning the investigation and studies of each component of the group (24)
Often, we do not know why we are studying that content (18)	The teacher does not teach, he guides the work (14)	Responsibility for results (13)
There is a repetition of the book's content without discussion and without application (22)	Working with the different components of the team was difficult (7)	Constant search for information, guidance, collection, selection and systematization of knowledge (24)
The tests are to classify, to grade. (24)	Teamwork was carried out with a schedule of activities (8)	Presence of seminars with the evaluation of colleagues and the teacher (18)
Monotonous lesson. Just study what they talk about and you pass (14)	Elaboration of questions and explanation of the questions that the problem situation needed (14)	Interpret data, make conclusions (5)
Teacher speaks, student writes down, studies and ready (12)	Survey of hypotheses and possible explanations about the problem (10)	

Note: the number in parentheses corresponds to the number of students who performed such verbalization.

5 Final Remarks

It is well known that the development of learning also occurs in the long term, especially through the student's ability to mobilize knowledge and apply it in new everyday situations. However, the results obtained indicate that it is of fundamental importance to alert to the need of learning other competences, such as scientific reasoning, self-regulation, and autonomy in the learning process (Vasconcelos, 2012). These characteristics are described in the students' verbalizations in Table 1, when they describe the characteristics of the classes with the PBL method. From the above, this study presents several evidences that the adoption of active learning strategies and methods in Engineering Education offers Engineering students better conditions for the development of structuring skills and competences so that they act properly in their professional field. Thus, this study is yet another example that shows that problem-based learning (PBL) has the potential to increase problem-solving skills, independent learning, and the ability to develop teamwork (PRINCE et al., 2005).

In addition to these aspects, in Table 1, verbalizations related to the characteristics of raising questions, being a motivating method, among others, are present. These testimonies show that PBL favors the development of questioning skills and that decision making and investigation are present in the process of learning. PBL presents students with the opportunity to deal with processes that tend to develop autonomy, decision making, and teamwork. In a learning environment conceived using PBL, students are the agents of their learning, authors of the construction of their knowledge through various collective and investigative actions. Sadeh and Zion (2009), point out that PBL involves processes that promote the development of critical and reflective thinking about the process, also involving emotional aspects, such as curiosity.

The PBL experience carried out in the Basic and Experimental Chemistry course proved to be a learning environment with great potential in the context of Engineering Education. The experience described and analyzed was developed in only one course, but, as in other studies, it indicated that PBL is an active learning method that is conducive to the occurrence of meaningful learning. This study is not a complete analysis of the analyzed phenomenon, but it has great potential to promote the occurrence of meaningful learning in Engineering Education.

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Active methodology: the experience of the Land Regularization Commission (CRF-UFPA) in the qualification of registry agents

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Abstract

When the comprehension of a natural phenomenon comprises a theoretical background, such knowledge can be accessed more quickly when faced with a similar situation (Godden and Baddeley, 1975; Prawat, 1989; Tavares, 2018). Therefore, we believe that the context of university extension contributes to the formation of citizens, as it presents the contact of academics with society, in which the theories learned in the classroom occurs. Practical experience plays an essential role in adults' training since living with real market situations enables them to solve problems more quickly and efficiently. Thus, this study aimed to present the Land Regularization Commission (CRF) experience using the active Problem-based learning (PBL) methodology as a teaching-and-learning strategy for the territorial physical survey team. With a qualitative approach, this study described the methodological strategy of selection and training registry agents for the "Meu Endereço'' extension project, developed through a partnership between the Science and Technology Secretariat of Pará State (SECTET), and the Federal University of Pará (UFPA) through its CRF. As a result, we observed that the PBL methodology proved efficient in developing teamwork, proactivity, and sensitivity. It stimulates discussion in all work execution stages. It makes the professional / student establish other relationships than merely performing a task.

Keywords: PBL training; University extension project; Interdisciplinarity.

1 Introduction

Throughout the labor market changes, new activities have emerged as indispensable elements in searching for competitive diversity, such as information technology (Santiago, 2016). It seems to be at the top of skills that the labor market requires, but not the only one, demanding younger graduates with higher holistic competencies. Although such demand is an upward trend, the labor market misunderstands how schools with many curricular subjects during graduation can fit perfectly into the professional profile that the market expects? To Tavares (2018), placing students in collaborative and active environments improves practical learning, turning egresses more prepared to face the diversities of the labor market. In those environments, they can work in groups to solve concrete problems, produce artifacts, develop content, participate in a debate, or win the game stages. It develops the skills and competencies with excellent performance.

According to the National Curricular Guidelines for Engineering (BRASIL, 2002), Art. 3, the egress must develop new technologies, according to the current events, and mainly to solve problems that may arise in this process (Vieira,2015). In this perspective, active methodologies are essential to achieve this goal. They are teaching and learning models that differ from the traditional methodology in terms of dynamics. It assumes that watching lectures and reproducing exercises are way less effective than actively interacting with tutors and partners. For this reason, the relationship between the labor market, Higher Education Institutions (HEI), and professional training is the central theme of this article.

Then, the research question follows up the CRF need of developing multiple skills in registry agents: How can we develop registry agents to work on-site with urban regularization activities? How can active learning methods such as PBL address this educational gap? Therefore, this essay aimed to demonstrate how training courses based on active methodology such as Problem-Based Learning (PBL) develop the demanded skills from registry agents in a Land Regularization Project developed in Northern Brazil. This project, called "Meu Endereço - Lugar de Paz e Segurança Social" (My Address - Place of Peace and Social Security), develops technical assistance to low-income households in the metropolitan area of Belém (RMB). It results from a partnership between the Government of Pará State and the Federal University of Pará (UFPA), a Department designed to do so (Land Regularization Commission - CRF). Presenting a descriptive form and qualitative approach, we present the experience of training the registry agents to work in the Multipurpose Technical registry (MTR) in the Cabanagem neighborhood. We highlight that this is a scientific paper based on empirical studies. For that reason, the following four sections as a theoretical framework to develop the case study.

2 Higher education and socioeconomic issues

According to Pieri (2018), the human capital theory developed in the last forty years establishes a relationship between individual investments in education and future returns in the labor market. This author has tested this theory empirically. Experiments in several economies have shown a causal relationship between education and success in the labor market, measured as higher wages and shorter periods of unemployment. When starting the academic journey, we hear that the only way to change our lives is through education. Those who commit themselves to this long journey believe that education is indeed transformative. Even if the path leads to a successful position in the labor market, the consensus is that the social benefits of investment in education go beyond. Concerning these benefits, Pieri (2018) states a big difference in economic and social performance between individuals who have studied more than those who are less educated. Higher educated people tend to live longer, with better health conditions, get jobs with higher salaries, and are less likely to engage in criminal activities.

According to him, Brazil's wage differences reach 230% between those who have finished high school and those who have just finished elementary school. Pieri (op cit.) still reveals that the unemployment statistics affect people much less than those with higher education. According to him, in 2015, about 10.5% of the economically active population was unemployed. Nevertheless, among individuals with a college degree, unemployment was only 5.2%. This market demand for higher education professionals raises the unemployment rate among young people aged 15 to 24-year-old. In this way, Informatica transformations have resulted in profound changes in the labor market, mainly affecting young people. According to recent data, in 2017, 26 million people were unemployed in Latin America, out of which 10 million were younger than 24 years old. Because of these circumstances and the countless capacities that organizations look for in a professional, it is vital to understand how universities have been working to facilitate their students' insertion in the job market.

3 University triad in the knowledge development

In recent years, education in Brazil has undergone continuous changes influenced by several factors: either by the laws of the Brazilian Ministry of Education (MEC), by the peculiarities of public or private HEI's, or by the current increasingly globalized and competitive labor market. These factors influence and drive the national teaching guidelines, continuously structuring curricular courses and new teaching-and-learning methodologies. In this sense, HEI's play a transcendental role in transforming this process by encouraging the development and the incorporation of advanced teaching strategies based on active research and innovation. (Urresta, Urresta & Canacuán, 2019). These authors highlight the need to produce and discuss studies about the higher education formation and teaching-and-learning process. It occurs because Brazilian universities generally turn their quality and productivity measures to international parameters detached from local reality (Ferreira and Florio, 2018). Therefore, HEI's have improved their parameters through the university triad, namely teaching, researching, and mentoring. Such triad aims to fulfill labor market needs with well-prepared professionals and academia with scholars attained to societal non-solved problems.

In this sense, discussing and reflecting on how the University can help its students build a solid education and a successful professional life emerges as an educational urgency. For that, Pieri (2018) emphasizes that the ideal way of measuring the quality of education is a challenge that specialists have been facing for a long time. Is it essential to understand what society desires from educational systems and what kind of professionals HEI wants to graduate? Do we need to know if we conceive the future's great minds, the best scientists, and great entrepreneurs? Or if we want to train many people with minimal acceptable knowledge? Thus, we need to consider training professionals with diverse characteristics and skills to find quick solutions to the required problems and capable of directing behaviors and planning new methods.

4 University extension as the professional formation and an HEI-Society integration strategy

According to Rodrigues et al. (2013), university extension has a vital role concerning the contributions it can bring to society. These authors argue that the University shall present a conception of what the extension improves community life in general, practicing what has been learned in the classroom and developing it outside the academic bubble. From the moment this scholar-society contact occurs, benefits happen on both sides. The academic ends up learning much more when there is this contact. It becomes much more rewarding to practice the theory received within the classroom. (Rodrigues et al., 2013). At UFPA, the incentive for university extension comes from public notices or institutional partnerships. Students and teachers develop an interdisciplinary project related to their courses. The teacher acts as a tutor who guides the student's actions whenever requested and accompanying each stage of the Project's execution. For Carbonari and Pereira (2007), the academic extension, as a social responsibility, is part of the new culture. Such condition causes the most significant and most crucial change registered in the corporate, academic environment in recent years. In their vision, the great challenge of extension is to rethink the relationship between teaching and researching to attempt social needs and establish the extension's contributions to the deepening of citizenship and society's practical transformation. Thus, extension practice develops critical thinking. The on-site experience develops in the student to deal with situations previously unimaginable or even discussed in the classroom.

5 University extension as the professional formation and an HEI-Society integration strategy

The pedagogical theories that explain learning approaches consider the "subject" who learns the "object" and the "mediation" between the subject and the object carried out in society. Several forms of active teaching and learning methods have been developed in the last decades, such as Project or Problem-Based Learning - PBL, Flipped Classroom, Games oriented activities, or using simulations. Aligned to the PBL strategy, many curricula oriented to active guidelines operate in various colleges worldwide. The Harvard Business School was the pioneer in the active method by introducing group discussions about real problems as an essential part of the learning process (Penaforte, 2001; Neves, 2009). Therefore, problem-based learning (PBL) emerges from the past due to the social need for future egress to solve real problems. Given its impact on university education, the University of Aalborg (Denmark) developed it through the International Centre for Problem-Based Learning to answer upward demand for developing holistic and critical college egress skills (Aalborg University 2015 and Padrón & Martin, 2018).

In Brazil, few HEI's introduced the PBL throughout the 1990s in graduate (1993) and undergraduate (1997) courses. PBL is a method that emerged to instruct professionals, bridging the gap between theory and practice (Frost, 1996; Neves, 2009). In this perspective, the Land Regularization Commission (CRF) team, composed of teachers and technicians responsible for training new registry agents. CRF decided to adopt PBL to teach and transform the training into more dynamic and motivating. According to Samaddar and Mukhopadhyay (2014) and Restrepo (2005), the sequence of steps determined for applying the PBL method varies according to the learning goal's specificities and the local context. However, in different countries and HEI that have developed experiences with the application of PBL, majorly in health and business schools, the number of steps or activities to carry out the results are adapted. Thus, CRF adopted the following sequence to conduct the PBL in the registry agent course: Step 1 – Theme and problem analyses; Step 2 – Activation of previous knowledge; Step 3 – Work planning for preparing the data collection; Step 4 – Material presentation and problem discussion; and Step 5 – Evaluation.

6 The "Meu Endereço" project

The "Meu Endereço'' project appears as a university extension initiative to contribute to reducing the rate of urban socio-environmental conflicts in the seven pacification territories of the TerPaz State Program, exercise 2019, namely Terra Firme, Guamá, Jurunas, Cabanagem, Nova União, Benguí, and Icuí, located in the metropolitan area of Belém (RMB), capital of Pará State, Northern Brazil. The "Meu Endereço'' Project integrates actions of the Secretariat for Science, Technology, Professional, and Technological Education of the Pará State (SECTET) and the Federal University of Pará (UFPA) through the Land Regularization Commission (CRF). The Project has three main principles: technological innovation, multi-professional technical assistance, and social inclusion, which articulate engineering, architecture, urbanism, legal and communication, and social service, among others, under the perspective of guaranteeing the constitutional principle of the dignity of society. Such actions involve technicians from public and private institutions, public servants who work in conflict mediation, territory households, besides UFPA teachers, technicians, and students.

The work developed by the Project often requires a technical home visit to the properties. The registry agent goes to the property to interview and collect information from the household to technicians and students to prepare the project Kit. The project kit comprises technical pieces to settle the property's land title - as floorplans and basic projects, legal statements, and whatever document necessary to provide legal security of the land and social dignity. The technical visit proceeds by the teams of engineering, social, architecture, or legal sciences. The objective is to carry out the socioeconomic and physical-territorial registration of the property visited, that is, measures, social and neighborhood relations.

The physical territorial survey has always focused on many doubts concerning the engineering team's activities, mainly on measurements. As we know, measurement in engineering and architecture services has its particularities depending on its purpose. In the "Meu Endereço" project, the demands are diverse, such as property valuation, construction inspection, design attendance, household expectation, and legislation. Therefore, the lack of visit specialization resulted in many comings and goings to the field. Thus, the need to develop each team's role in solving specific problems and actively searching for knowledge motivated the adoption of PBL training.

6.1 Step 1 – Theme and problem analyses

The problem is the central element in PBL since learning begins when students face it (Neves, 2009). In this experience, the problem concerned creating a schematic sketch of the property visited that meets the requirements for making future technical pieces. Any person on the team does the same reading of the drawing? As a guide for thinking about solutions, we established the following guiding questions: the most frequent answers are in Figure 1.

• Q1. What information do we consider relevant for the engineering team to collect at the technical visit?

• Q2. What data is essential to collect?

• Q3. What instruments should we take with us on the visit?

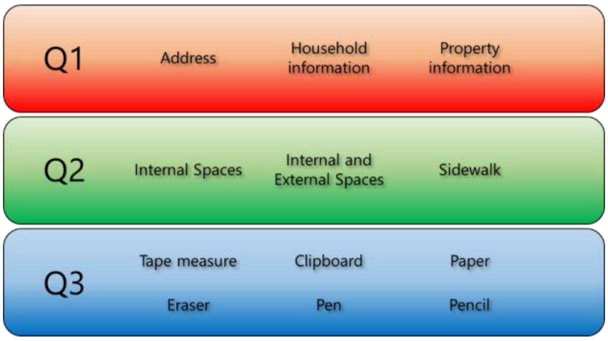

Figure 1. Result of the student's answers to the guiding questions.
Source: Research data

As a result, we found that many of our collaborators/students had not previously tried/experienced working on other engineering subjects such as land title regularization. The Engineering College focuses on civil construction and architecture, but other engineer's needed competencies lack social assistance and regulation accomplishment. Thus, the need to activate knowledge related to the field of land title regularization in step 2.

6.2 Step 2 – Activation of previous knowledge

In Step 2, we conducted instruction courses about land title regularization when the registry agents became aware of such subject's fundamentals and techniques. Figure 2 shows the students taking measurements where the theoretical class occurred to training field action.

Figure 2. Images of the theoretical and practical expository classes.
Research Data

At this stage, the lecture strategy adopted the use of PowerPoint. Here, the team of tutors addressed the main issues surrounding the issue of urban land regularization. It also addressed how the engineer's role within land regularization actions and schematic sketches, relevant real estate information, measurement and data collection equipment, approach, and design standards. After presenting the themes, we asked the participants what theme they would like to take a practical class to solve the existing doubts. By vote, we carried out a practice between the teams on the manipulation of the measuring tape. This activity aimed to train the registry agents' practical performance by identifying and assessing possible difficulties throughout the measuring protocol exercises.

6.3 Step 3 – Work planning for preparing the data collection

In Step 3, we proceeded to the composition, formation, and distribution of the team for the technical home visit stage. It was time to direct the team to the field survey (Figure 3) after the knowledge activation stage. We composed the teams in a multidisciplinary way of undergraduate students from engineering, architecture, geography, social work, and law, besides two local households from the surveyed community.

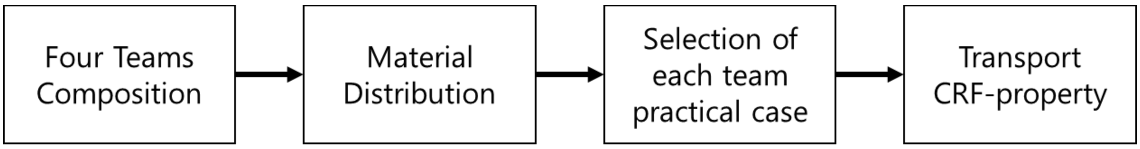

Figure 3. Field activity planning
Source: Research Data

The agents' profile was varied because among the community representatives. We sought to use a technical but accessible language to those who are not technicians nor academics. Figure 4 shows the team on a technical home visit. In this step, the registry agents should exercise the classroom lessons in practice, reaching local households and properties for surveying socioeconomic, socio-environmental, and urbanistic data. Interview skills, measuring, sketching, and photographing concerned some related skills to the practical activities.

Figure 4. Field activity
Source: Research Data

6.4 Step 4 – Material presentation and problem discussion

In Step 4, each team member had the opportunity to report their impressions of the technical visit. During the talk time (Figure 5), strong interaction with households was evident in the agents' discourse. It was common among the teams the perception that the registration exceeds the limits of data collection and advances to neighboring relationships. Then, the field survey often requires much more time than the planned one due to this willingness to bring residents closer.

Figure 5. Talk time
Source: Research Data

Also, we observed that the difficulty of measuring was not among the subjects. It took more effort to collect social data concerning land regularization, neighborhood conflict, housing improvement, and technical assistance to access government programs. Each situation aroused problems neither initially claimed by the households nor previously predicted by CRF, resulting in countless discussions on how to help them.

6.5 Step 5 – Evaluation

In Step 5, the validation stage, we conducted an expository class (Figure 6). We invited all teams to present the results of their technical visits (observations, sketches, photographs). The teams that were not presenting should analyze the technical parts of the team that was presenting. The objective was to carry out the survey's quality control and draw attention to the care that the survey requires.

In this step, the registry teams presented how they identified multiple site problems and managed conflict occurrences. Most of the teams revealed tool handling difficulties, poor photographic performance - leading to a lack of visual record.

Figure 6. Presentation class.
Source: Research Data

7 Final Remarks

According to Suguinoshita et al. (2017), multiple Brazilian schools seek to adopt active learning methods in their curricula to improve student performance. Those methods, such as PBL, represent a disruptive teaching and learning method at all educational levels, especially in team-based courses. The investigation and solving-problems based-actions lead the students to develop a critical sense, maturity, and teamwork competencies vital in a post-academic professional context. In this sense, we address the research question related to developing multiple skills in registry agents who work with urban regularization activities by active learning methods such as PBL.

In this sense, Brazilian students who enter higher education programs in the 21st century are younger than the last generation, with an average age range of 21 to 30, according to the ENEM (National High School Exam). Perhaps this prematurity is the central factor for the significant dropout rate in Brazilian HEI's. In the 2010 Census, there were 228,683 dropouts compared to 1,773,315 students enrolled in public HEI's, a dropout rate of 12.9%. This index shows that, of every 100 students entering the Brazilian university system, practically 13 are not successful in fulfilling curricular activities and graduating. (Sales Jr, 2011).

Because of this reality, Higher Education Institutions must find ways to make teaching and learning more motivating. Besides, they must add interactive teaching activities that lead the students to experience the labor market dynamics and prepare them to act proactively. The students must criticize and reflect on the social context in which they participate. Certainly, extension activities throughout academic life are robust instruments in achieving these goals. In the context that involves the functions of the Brazilian University, especially extension projects for junior companies and supervised internships may contribute significantly to their new perspective of placing their work at the service of the interests of the vast majority of the population. PBL actions do not exhaust the efforts made by higher institutions in searching the interaction and practical experience for their students and thus contribute to their employability as soon as they graduate.

Therefore, the lessons learned from such experience are notorious. The PBL application in the CRF project revealed an excellent teaching and learning strategy to develop registry agents for urban regularization. This approach resulted in good approval from multiple groups involved in the CRF - engineering professors, students, interns, and local households, which potentializes the interdisciplinary schedule enabled through active learning. By the PBL method, we efficiently assessed the development of the registry agents, allowing us to directly adjust the courses into a suitable approach to reduce weaknesses and improve strengths to assist extension projects better. For further research, we suggest investigating how PBL can be implemented in other subject extension courses, especially those related to public assistance. This research adds value to the literature in active learning to extension project purposes, developing on-site skills to address urban regularization activities. It also leads to a practical contribution to the professional development of urban regularization workers in the Brazilian Amazon, where cities need expressive levels to manage the urban land properly.

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Preparing Girls for Mathematics Olympiad

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Abstract

In this article, we present the subproject Mathematics Olympiad that integrated the project Encouraging Girls in Exact Sciences, Engineering, and Information Technology, at the University of Caxias do Sul. The referred subproject contemplated both planning and execution of workshops to prepare students for Mathematics Olympiad and was developed by a girls' team of undergraduate students, guided by university instructors, and assisted, in the initial stage, by an exchange student from University of Verona, Italy. For the planning of the workshops, the students raised recurring themes in Brazilian Mathematics Olympiad for Public Schools and carried out diagnostic evaluations to identify difficulties of co-executing schools' students. The workshops were developed based on the active learning strategy "Challenge in Groups" for the resolution of questions and problems already applied in Brazilian Mathematics Olympiad for Public Schools. At each meeting, the number of the group members was reduced, so that little by little the students could be able to work individually. After this stage of preparation, the girls 'team of undergraduate students selected new questions and assisted in the organization and conduct of mini Olympiad (Phase 1) with a classificatory nature. Five public schools from the UCS coverage region participated, with all students interested and divided by levels: Level 1 for 6th and 7th grades and Level 2 for 8th and 9th grades of Elementary School, and Level 3 for High School. The three students with the best performance at each level went on to Phase 2, representing their schools at the University of Caxias do Sul Mathematics Olympiad 2019. In Phase 2, the undergraduate students sought questions from previous Olympics of greater complexity to challenge and highlight the best students with gold, silver, and bronze medals, and their schools with first, second and third place trophies. In developing this important study and engagement project for the co-executing schools' students, the undergraduate students also collaborated to develop autonomy and self-confidence in the co-executing schools' students, encouraging them to participate in OBMEP.

Keywords: Mathematics Olympiad; Active Learning; Mathematics Workshops.

1 Introduction

During the history that includes the great discoveries in the area of sciences and technologies, the names of women mathematicians, physicists and chemists generally do not have the same greatness of recognition as the male scientists of the time. This reinforces that the difficulties of women's insertion in this area is a dilemma that, even at different levels of equity, is found on the world stage. It is of most importance this valorization of women as well as the constancy in what refers to the study in the area of exact sciences, promoting in girls self-confidence, encouragement and, above all, the feeling of belonging, directly linked to the increase in mathematical performance. (Thrasher, 2008; Gavin & Reis, 2003; Buser & Yuan, 2019; Salmon, 2015; Rimer, 2008).

Over the past few decades, attracting girls to science has been an apprehension for many researchers concerned with gender issues and with the importance of female participation in science, technology engineering and mathematics (STEM) (Rasmussen & Hapnes, 1991; Anderson, 1994; NSF, 1998; Blickenstaff, 2005; Du & Kolmos, 2009; Tessari & Villas-Boas, 2013; Dasgupta & Stout, 2014; González-González et al, 2018; Sauer et al, 2020a; Sauer et al, 2020b).

In Brazil, the process of insertion of women in scientific and technological careers occurred in the same proportions as in other countries of the world, however, during much of the twentieth century there was still a great prejudice related to women's aptitude or even to their intellectual abilities to pursue these careers (Tessari

& Villas-Boas, 2013). In the last decade, a considerable number of public calls aiming to support projects intended for stimulating the education of women for careers in Exact Sciences, Engineering and Information Technology in Brazil has been launched.

Since 2009, a group of instructors from the University of Caxias do Sul (UCS), a community institution of higher education located in the southern region of Brazil, has been developing projects for encouraging girls for careers in Exact Sciences, Engineering, and Information Technology. In 2018, this group of instructors had a project approved in a public call of the National Council for Research and Development (CNPq), the "Encouraging Girls in Exact Sciences, Engineering and Information Technology" (EMC&T).

In this project context, and in order to improve the participation and female award indices in the Brazilian Mathematics Olympiad of Public Schools (OBMEP in the Portuguese acronym), a subproject named "Olimpíadas de Matemática" (OlimMat) was created. In this subproject, preparation workshops for local Mathematics Olympiad were planned and carried out at the co-executing schools of EMC&T, and later at UCS.

OBMEP is a nationwide project aimed at Brazilian schools, public and private, carried out by the Institute of Pure and Applied Mathematics (IMPA) and with support from the Brazilian Mathematical Society (SBM). OBMEP has as some of its main objectives to stimulate and promote the study of Mathematics, to contribute to the improvement of the quality of basic education, to identify young talents and to encourage the improvement of public-school teachers (OBMEP, 2021).

In OBMEP the participants are students from the 6th year of Elementary School until the last year of High School, divided into levels, namely: Level 1 to 6th and 7th years of Elementary School, Level 2 to 8th and 9th years of Elementary School and Level 3 for high school students (OBMEP, 2021). In the first phase, which takes place in schools, the tests are made up of objective questions and all students from public and private schools are invited to participate. In the second phase, participate 5% of the students with the best performance in the first one, with a discursive test, applied in specified places, outside the school, designated by the national organization.

An analysis of official OBMEP data (http://www.obmep.org.br/em-numeros.htm) reveals that from 2005, when it was created, until 2019, the awards to girls have always been lower than those to boys, both in number of gold, silver, and bronze medals and honorable mentions, even with several initiatives to encourage girls' participation in science competitions.

In 2005 the girls had the worst results in the number of bronze medals and honorable mentions, and in 2007 they had the worst results in gold and silver medals. As for the girls' best results, these occurred in 2016, when they obtained the best results of all competitions in the analyzed period.

As for the number of medals, the highest percentage of girls gold medalists was 23.15% in 2016. The highest percentage ever reached by the female audience at the awards also occurred in 2016, with 40.32% of the honorable mentions being destinated for girls (OBMEP, 2021).

Even so, the percentage is well below that achieved by boys in the same year, and this was also the case for silver and bronze medals. The lowest percentage of gold medals won by girls happened in 2007, when the female audience represented 14.95%.

However, data on the classification for the second phase of the OBMEP reveal that "since 2006, at the three levels, approximately half of the students classified for the second phase are girls. Therefore, in all age groups, approximately half of the top 5% math students are girls" (IMPA, 2019).

Considering then that the test in the second phase has been held with equal numbers of boys and girls, the number of boys awarded has been expressively higher.

Therefore, as preparation workshops for the Mathematics Olympiad, as part of the activities of the EMC&T program, they aim to encourage the study and development of mathematical skills, but also had a social feeling for the insertion, incentive and encouragement of girls students to participate preparing themselves to face the challenge of OBMEP with the same conditions and resources as boys. The application of the workshops by young undergraduate students, who chose to dedicate their careers to the exact sciences, encourages girls to think of Science and Mathematics as possible paths for the future, expanding female representation and a consolidation of the concept of gender equality. As stated by Freire (1996), "Sometimes, one barely imagines what a simple gesture from the teacher can represent in a student's life. What can an apparently insignificant gesture be worth as a formative force or as a contribution to the assumption of the student by himself."

The design methodology, preparation, and application of the workshops, a description of the Olympiad in the schools, the stage at UCS, and some results and conclusions are presented below.

2 Method

The preparation workshops for OlimMat took place in schools and were implemented by undergraduate scholarship students from the Exact Sciences courses (Engineering, Physics and Mathematics) at UCS, under the supervision of a master's student exchange student and teachers, members of the EMC&T Project team (Figures 1 and 2).

Figures 1 and 2. Image of the members of EMC&T Program team, authors' collection.

After the planning, done at UCS, through seminars, the execution of the workshops occurred in five stages, including moments of analysis of results, accompanied by studies, in the intervals between each stage. At the end of the workshops, each school held its own Olympiad, and the best ranked students then participated in the OlimMat at UCS, ending with an awards ceremony to close the activities. The methodology is described below.

2.1 Planning of the OlimMat Stages

The planning of the preparation workshops for the Mathematics Olympiad at UCS was based on the active learning strategy known as Challenge in Groups (Elmôr-Filho et al, 2019) and was structured based on the learning objectives organized in Bloom's Taxonomy, seeking to reach higher levels of complexity. In the classroom, when applying the methodology, the intention was to create a relaxed, safe, and slightly competitive environment in order to engage the participants in the activities, promote the exercise of cooperation, as performances depended on everyone in the team, and encourage the personal development of each student. At the end of each meeting, the members of the winning team were awarded with symbolic prizes.

Bloom's Taxonomy has guided planning and practice so that it is possible to evaluate and stimulate students' performance at different levels of knowledge construction, exploring, remembering, and understanding in the review and deepening of theoretical content; to apply and to analyze the resolution of questions in simulations; and to evaluate and to create by developing other colleagues' own methods of resolution and evaluation of resolutions.

Bloom's Taxonomy has also collaborated to encourage educators, who accompanied the workshops, to think strategies to help their students, in a structured and conscious way, to acquire specific skills from the perception of the need to master simpler skills (facts) for, later, master the most complex (concepts) (Ferraz and Belhot, 2010).

In the application of the workshops, emphasis was placed on active learning, placing the students as protagonists of the learning itself. The performance of undergraduate scholarship students was oriented to conduct activities in such a way that students felt motivated to apply and produce knowledge, interact and share their experiences, to strengthen the team and, thus, qualifying the educational process. Active learning can result from any teaching method as long as it engages students in the learning process, which therefore requires that they perform meaningful activities and reason about what they are doing (Elmôr-Filho, Zanol Sauer, Almeida and Villas-Boas, 2019).

Freire (1996) also emphasizes the attention regarding the respect for the student's autonomy and identity, since through this means the mobilization of his knowledge takes place, which propels him to new discoveries and conceptions.

The workshop activities were proposed aiming to awaken the students' imagination, intuition, and curiosity in a natural way, considering that "The more spontaneous curiosity is intensified, but above all it is 'rigorized', the more epistemological it becomes" (FREIRE, 1996).

2.2 Preparation Studies at UCS

The first stage of the workshops was for theoretical and procedural preparation and taught by an exchange student for undergraduate scholarship students, preparing the girls for later application in schools. From a survey of the most recurrent themes in the OBMEP tests, each meeting was focused on one of the topics of mathematics among the following: rules of standards; counting permutations and combinations; logic; diagrams; visual subtraction and subtraction; order of operations; inequalities; analytical geometry; fractions; basic statistics; expressions with unknowns and equations and percentages.

In the preparation meetings at UCS, initially the theme of the day was presented and OBMEP questions from previous years related to the content were solved. During pre-determined times, each scholarship holder solved the questions individually and then discussions were promoted about difficulties and possible resolution, considering the target audience. Thus, through interaction and sharing of knowledge, it was guaranteed that different resolutions were explored and that all the fellows were prepared for the application in schools.

2.3 Diagnostic Evaluation

In the first meeting in the schools, a diagnostic evaluation was performed, prepared by the undergraduate scholarship students, with easy, medium, and difficult questions, covering all the topics that would be covered. Each student solved the questions individually and was asked to solve them as detailed as possible, so that it was possible to identify knowledge, difficulties, and the type of errors, if any.

During the analysis of the resolutions, the right and wrong answers were analyzed, and in subsequent meetings the questions with content that presented the biggest gaps were emphasized, according to the particularities of each school. With this, it was possible to improve the workshop activities, giving more attention to situations in which the girls presented the greatest need.

2.4 Girls' Preparation in Schools

Among the five schools participating in the program, all from the region covered by UCS, three are elementary and high schools, one is a middle school, and the fifth is a high school.

The workshops took place over six weeks, with weekly meetings of four hours, with a 30-minute break, and in shifts opposite to the school classes. Although the main objective was to encourage women in Science, Mathematics and Engineering, providing encouragement and self-confidence to girls, in the Group Challenge there was also the participation of male students (Figures 3 and 4).

Figures 3 and 4. Images of the workshops with the Group Challenge, author's collection.

By working with mixed teams, we sought some adaptation to the school environment and its routine, considering the difficulty of separating boys and girls in this first stage. With this characteristic, we also explored the benefits that this shared work provides. Freire (1996) defends true dialogicity, where individuals learn and grow from differences, creating a bond of respect for the autonomy and opinion of others.

The classes were composed, on average, of 20 students from the 6th to 9th grades of elementary school and 20 students from the three years of high school. When the number of participants exceeded the limit for a good quality of the methodology's application, two groups were formed and a new day of the week was chosen to attend to everyone, avoiding dispersion of the students' attention and focus.

2.4.1 Content review

Following the planning guidelines, prior to the application of the Group Challenge strategy, a brief review of concepts was held, in an expository manner, for a maximum of 15 minutes, with an introduction involving each mathematical topic present in the questions that the students would later solve.

It was noted that a large part of the students had difficulties with elementary mathematical concepts, and practically all of them had difficulties interpreting the questions. Over time, the students got used to doing the activities and discussing the resolutions, thus providing the development of competencies and skills that also contribute to the understanding of the questions.

2.4.2 Group Challenge

The Group Challenge contains 5 stages of application. In step 1, instructions are provided about the execution of the activity, informing the girls about the main topic of the dynamic. For each meeting questions of the same nature were separated, contemplating a topic among those mentioned in subsection 2.1.

In the execution of stage 2, the teams were divided, and each group was represented by two of its members, who solved the problems drawn in each round on the board. Everyone went to the board at least once, and for each correct answer a point was added to the team. The groups were diversified throughout the meetings so that, in this way, the girls could socialize their thoughts with as many colleagues as possible.

In step 3, each group presented a solution to a problem, and the colleagues followed the resolution and wrote it down in their notebooks. The participants at the board had no access to support material but were allowed to interact with their colleagues at the tables. In step 4, the teams evaluated their opponents' resolutions, and in cases where there was nothing to add, the group won the score. When the other group identified some error in the development of the question presented by their colleague, this group received a score.

In step 5, the teacher discussed the questions and their resolution, clarifying doubts and making the necessary records. This moment, in the application of the Group Challenge, is extremely relevant, because it allows errors to be noticed and methods to be improved.

As the activities went on, the larger groups were reduced so that the girls could develop the autonomy and confidence to solve the math problems by themselves, thus preparing them for the next step - the first phase of the exam.

At the end of each workshop the winning group was presented with a symbolic reward, but all the students who participated in the dynamic were also recognized and presented with a gift. This small competition encouraged everyone to improve their individual performance and productivity, and to be in the next winning group.

2.4.3 Strategy for conducting long tests

During the preparation workshops, it was noticed that the girls had difficulties in solving long tests, thus the need to solve doubts related to this arose.

In moments of exchange of ideas, short instructions were created and passed to the students, trying to encourage them to face more complex questions. Auxiliary resources, provided by the exchange student, were discussed during the meetings with the students, such as the use of the method of exclusion of alternatives, for the case of objective tests, and, when the questions were similar or difficult to understand, it was suggested to start with the easiest and best understood problems.

To encourage the student's problem-solving and persistence, a maximum time of 7 and a half minutes was stipulated for the completion of each question present in the test of phase 1 of OlimMat, instructing that, in case of an obstacle or indecision, a change of questions would be chosen, contributing to the complete completion of the test.

2.5 Olympiad in Schools

After the preparation workshops, Phase 1 of the Olympiad was held in the schools, with the test being open to all students. At the school, the students were separated into classes by test levels (Level 1, Level 2 or Level 3) and each class was accompanied by a teacher or person in charge (Figure 5).

Figure 5. Image of the students on Phase 1 of the Mathematics Olympiad at Tancredo Neves School, author's collection.

The tests were developed along the lines of Phase 1 of the OBMEP, that is: objective test, of a classification nature, composed of twenty multiple choice questions, each worth one point, totaling twenty points, where each question had five answer options (A, B, C, D and E), among which only one was correct. The duration of the test was two hours and thirty minutes, except for students with special needs who needed assistance, such as Braille or magnified tests, for which the duration was three hours and thirty minutes.

After the exams were corrected, the students and their math teachers - who obtained the best results - were awarded prizes. Girls were awarded gold, silver and bronze medals to the first three places on each level, as well as boys. His mathematics teachers received certificates of honor to the merit.

2.6 Olympiad at UCS

The students classified in phase 1 participated in a new test, representing their school, in phase 2. The second test was held at UCS - Central Campus, in which 72 students participated (Figure 6). The test was prepared with essay questions along the lines of the OBMEP. The undergraduate scholarship holders supervised, in order to avoid fraud, and corrected the exams.

The award ceremony took place in the same place as the test, with representatives from the five participating schools, students and their families. In the awarding of the second phase, the participants were separated into two categories: best girls and best boys, also receiving gold, silver and bronze medals for the best placed.

As awards, the teachers received certificates of merit and a math book. The participating schools received first, second and third place trophies, based on the performance of their students, and book kits were awarded to the five schools. The highlight of the Level 3 awards was that the high school students, gold medalists, also won university scholarships, with a choice of courses in Exact Science, Engineering, and Computing.

Figure 6. Image of the students on Phase 2 of OlimMat at UCS, authors' collection.

3 Results

Throughout the application of the Group Challenge strategy, it was noticeable the gradual increase in the students' participation and enthusiasm for the proposal. A notable improvement was noticed during the chats and the integration among class members.

During the application of the evaluation in the 1st phase, all the students respected the rules and demonstrated commitment in performing the activities, as well as respecting the timetable and waiting for the other students to finish their evaluations.

Among the five participating institutions, an estimated 150 students participated in Level 1, 52% of whom were girls. At Level 2, 110 students participated, 48% of whom were girls. For Level 3, 230 students were accounted for, 49% of whom were girls. With these data, the promising results that the strategy applied to the girls can be extolled.

In view of the analysis of the answers obtained in the three levels, it is possible to highlight the significant increase in the averages obtained in OlimMat - 2019 (in relation to those of the OBMEP that occurred on May 21, 2019), which may have been propitiated by the directed studies carried out during the Encouraging Girls in Science Project, taught since March 2019, in the afterschool, added to the Group Challenge strategy, which intensified the studies and sharpened the students' goal.

The students selected to participate in the 2nd phase of OlimMat showed commitment and dedication in solving the problems proposed for study, attending the meetings, and making assertive choices. Some students went further, studying at home previous editions of phase 2 of OBMEP. These students sought out the school's mathematics teachers daily to ask questions or clarify the issues they were trying to solve in their studies. Attitudes like this show that, in fact, there was a change in attitude of these students, who felt motivated and encouraged to seek more, generating, in addition to knowledge and development of logical-mathematical reasoning, interest in learning and autonomy.

During the OlimMat awards, subdivided into awards for boys and awards for girls, it was possible to highlight the feeling of recognition, capacity and competence felt by the students. The possibility of achieving their goals through dedication and studies gave each OlimMat participant the awareness that they are capable and deserving of what they aim for.

4 Conclusion

From the development of this subproject, it was possible to notice a great evolution in the girls, both in the cognitive and social areas and in the behavioral and educational areas. Furthermore, the development of the students' autonomy and self-confidence is evident.

The OlimMat represented a motivation for dynamic activities, acting as a facilitator in deconstructing the idea that Exact Sciences are difficult to understand. When preparing the workshops, the whole team was concerned with bringing practical, uncomplicated explanations to the young people, in order to make learning more concrete.

Therefore, it can be seen that the work done in the subproject brought many benefits both to those who were assigned to it and those who applied it, because education is a double track that is always aimed at the constant development of all those involved.

This promotes the beginning of a process to break paradigms and stereotypes that segregate girls and women. With the extinction of such prejudices, everyone should exercise their choices with more freedom, being able to better develop their skills and participate significantly in the advancement of scientific and technological knowledge. Thus, it is important to emphasize that it is extremely important to implement projects to encourage and value female participation in the STEM field.

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Mechanical Engineering Students Project-Based Learning in OUAS

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Abstract

Oulu University of Applied Sciences (OUAS) is in the Norther Finland, in the city of Oulu. It has c.a. 9500 students and 500 staff members. The School of Engineering and Natural Resources as c.a. 2400 students, and c.a. 150 staff members, which makes it largest of the Schools of the OUAS. This paper introduces project-based learning approach which is used in the School of Engineering and Natural Resources, Mechanical Engineering department to get local companies to offer project works to mechanical engineering students. The concept is based on organizing a local event or online event for the companies to come to OUAS campus to present their challenges needing engineering students to solve. The companies are then competing, selling or pitching, their problem for engineering students as the engineering students will then individually select the most interesting cases to be solved, and which has linkage to potential summer job and thesis work opportunities if projects are successful. The proposed project topics vary from factory level to single mechanical device building, and industry areas range from high tech industry to healthcare to wood industry, as the application potential of mechanical engineering is wide. The concept has proven to be successful, and it has been established as traditional event with many companies returning to the pitching event annually to get their industry problems solved by group of engineering students.

Keywords: Project-based Learning; Industry Collaboration; Active Learning; Engineering Education; Project based Learning; Project Approaches.

1 Introduction

In Finland, Universities of Applied Sciences (UAS) offer Bachelor of Engineering Education and the curriculums of the engineering degrees are designed to serve the needs of the private and public companies, organizations, and the society. Especially, the engineering degrees are designed from working life perspective to offer as good fit as possible for new engineers to have such a set of skills which are currently needed in the companies. The Oulu University of Applied Sciences (OUAS) mechanical engineering special focus is given to networking and communication skills, as these skills are essential in the current working life. The engineers work is in many cases project based, and these projects are multidisciplinary. The mechanical engineering degree program aims to bridge the transition from studies to industry so that there is easy and fast transition from school to working life.

Learning does not happen, and projects are not completed without feasible target setting. For some motivating target is to just finalize the tasks at hand, but for many, the essential factor for motivation is to acquire skills which have direct linkage to employment after completion of the education (Kekkonen & Juntunen 2019). That gives especially for Universities of Applied Sciences special role to ensure the fit of engineering education curriculum to the needs of the working life. Additionally, engineering education faces many demands as the working life also changes rapidly (Kropsu-Vehkaperä et al. 2013). Project based learning offers flexibility for curriculum design.

Universities of Applied Sciences and the industry have many collaboration programs. For example, the European Union (EU) funded research, development and innovation (RDI) projects offers a great platform for impactful development projects, in which the UAS can develop their activities and laboratories and can via these programs support the deployment of new technologies to companies. Also, the UAS can then offer new engineers with skills on new technology to industry.

1.1 OUAS RDI Program started systematic project-based collaboration with SMEs

One example of successful EU funded program was the OUAS mechanical engineering program called "TEHOJA", which was executed together with the companies during 2016–2020. The program started 2016 with the aim of helping local companies to take into use new automation technologies, which could bring the companies competitive advantages on cost, delivery schedules and product quality. The program focused on finding suitable application environments to collaborative robotics, called 'Cobots', in the local small and medium sized (SME) companies. These 'Cobot' application were piloted during the program in the actual companies. Program main targets was to expand local SMEs knowledge of the collaboration robotics and their application to enhance production, and to train companies' personnel to apply these new collaboration robotics technologies. (Broström, Kaivosoja & Kekkonen, 2019).

Before start of the program the collaboration with local SME's and OUAS mechanical engineering education program was not systematic and one of the issues which needed to be solved was the engagement of the local SME's to start collaboration with OUAS. To resolve this need for systematic and wide collaboration the Mechanical Engineering Pitching Event (MEPE) was established, This MEPE event brings annually local SME's and 3rd year mechanical engineering students together. In this MEPE event the local SMEs are pitching their challenges for the students. Companies are competing to get best students to work on their challenges, so they need to "sell" their challenges to students via pitching type of event, which is known for start-up companies as they sell their business idea to investors. Students will then select their project work topic for the spring semester based on the SME's presentations. This will also give companies participating to MEPE event, a possibility to also get summer trainees for the following summer or thesis workers, as the project work team members will be known by the company, and the students team will know also the companies' processes, products and development opportunities making it easier and faster for the company to employ the students for value adding work in the company.

2 Mechanical Engineering Studies and the Pitching Event (MEPE)

Right from the start Mechanical Engineering studies are aiming to teach students how to master product design and project management activities. First year students are learning basic courses on mathematics and physics but also additionally they have for first year semester course called 'Innovative Product Development'. In this course, the students are leaning the product development process phases, and finally they are designing and building their own product which they have invented. At the end of the course, there is product exhibitions. Some new products have been patented and the licensed, based on their novelty and innovativeness.

During second year of studies the mechanical engineering students are deepening their knowledge on theory and professional understanding on mechanical engineering, these studies will be completed during the third year of studies. Additionally, students have gained practical experience from summer jobs between the semesters. Now the needed basic understanding to take more demanding assignments from the industry (Kekkonen & Juntunen, 2018).

The Mechanical Engineering Pitching Event (MEPE) is organized annually the beginning of Autum semester, when the new season has just started. The preparatory work has been already started in the spring semester to ensure companies participation to MEPE. In many instances, the closing meeting of the previous projects are best occasions to recruit companies to continue to work with OUAS via MEPE. When companies experience the value of the MEPE it is easier to convince them to continue also in the following year. Naturally also new companies, especially micro companies or SMEs are welcomed to the MEPE, and these companies are search actively to grow the MEPE participant numbers.

At first the companies might experience difficulties in defining their project topics as development resources are scarce especially in small companies (Isoherranen and Ratnayake, 2018). To help companies to define their development project topics the education staff from the School of Engineering and Natural Resources visits the company on site to understand better the company operations and business. Then they can support companies to define their development project topics, which companies are then presenting in the MEPE event. The MEPE event can be virtual event or local event in the OUAS campus. After the pitching, in the following day students can select the most interesting project topics. The selection is then approved by the education staff via specific interview to ensure the fit and skills of the students for the specific defined project. It is essential the previous studies are completed before entering the project-based learning in actual real-life case company, to ensure that needed background knowledge is enabling successful project completion.

Once the project work has been selected, the students start planning their project planning together with the teachers, and then proceed to kick-off meeting with the companies. After kick-off meeting the actual project plan is made and all the parties need to approve the project plan before start of the project. The project work starts then in the company beginning of the spring semester and is finalized by the end of May. During the spring semester the project execution is followed rigorously to ensure successful development project for company and excellent learning experience for the student.

3 Examples of student projects

1.2 Case 1, Plastic bottle clamp

Head Recycle Systems (HRS) is developing innovative plastic recycling equipment's in Oulu area . This company has participated in 2019 to MEPE for the second time, encouraged by the good experiences of the previous year. They came to event to look for enthusiastic mechanical engineers for a product development project. The project topic focused on development of a new type of mechanical plastic recycling equipment. This project was executed by four mechanical engineering students focused on machine automation and machine building.

The project team was largely given free hands to innovate and develop. Students team was only given certain boundaries to work with but there was plenty of room for creativity and "out of the box" thinking. With the help of this freedom, a new way to construct device, was invented and developed during the project, which will be utilized in the future development of machinery and equipment for HRS client.

The result of the project was a fully functional device that met the client's requirements (see Figures 1 and 2), i.e. the goals of the project were totally achieved. The project team worked as a team systematically and learned many new things in several different sub-areas of product design. Project team describes that the best moment of the project was the completion of the prototype, as well as its initial tests. All the work crystallized into the moment when everyone could see the imprint of their own hands, as well as the realization of common visions and goals. (Heinonen, et al. 2020).

Figure 1. 3D-printed Proof of Concept

Results of this project was a successfully constructed machine with new innovative concepts. All teams engineering students continued cooperation with this company as a Thesis workers. One of the students also got his first job from the HRS company. The projects gave a lot for the students: opportunity to test their engineering skills in real environment. Also, this project helps to get valuable feedback on the content of mechanical engineering courses and their relevance to real working life demands of the companies.

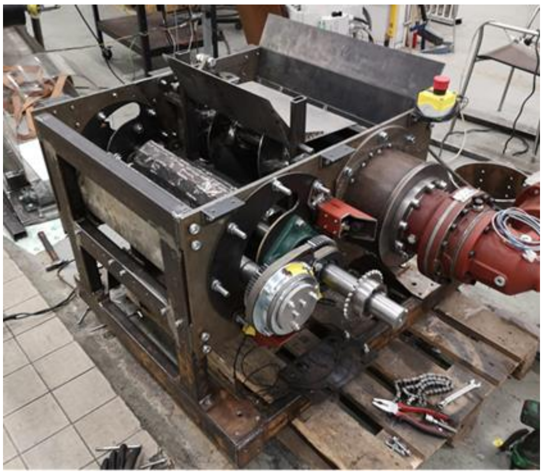

Figure 2. Picture of Working prototype of the product

For the HRS company the result of the project was an innovative prototype, produced with flexibly and at a reasonable cost by the engineering students team. The company was satisfied with the competence, innovation, and cooperation skills of the project team.

1.3 Case 2, 5S implementation in metal workshop

This case project was presented in MEPE in 2019. During 2019 JMC Engine Oy underwent a 5S pilot project for one machine cell. The positive feedback from the operators and improved worksite tidiness was resulted from the pilot 5S project. As a result, the company decided to expand this project to cover the whole production site.

The goal of this project was to expand the 5S methodology to the rest of the factory site, promote Lean culture and build a quality and measurement control tool to sustain the changes made within 5S. The aim of the project was to improve job satisfaction, safety, work environment and to eliminate waste from the production. JMC Engine Oy underwent a 5S pilot project for one machine cell. The positive feedback from the operators and improved worksite tidiness was resulted from the pilot 5S project (see Figure 3). As a result, the company decided to expand this project to cover the whole production site and also expand understanding of personnel about 5S method with practical training.

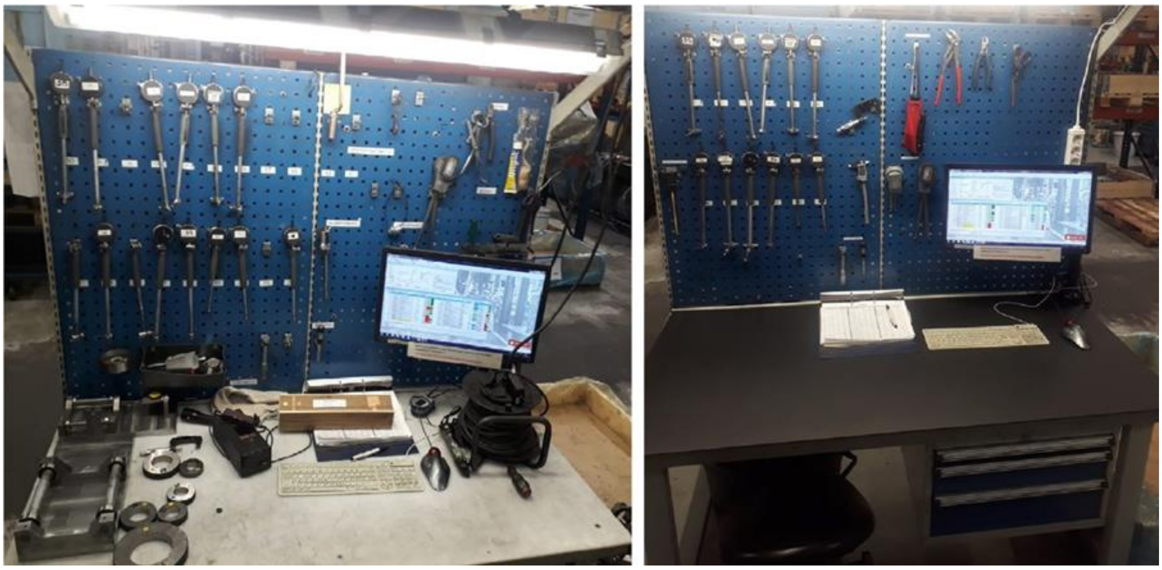

Figure 3. Picture of MCM 510 Workstation before and after the 5S organizing.

In the end of project, the personnel 5S training package was implemented together with the staff of the POTKUA- project. The aim of the training was to teach employees through the 5S theory and practice. At first, theory section was held, where the employees were educated what 5S stands for and what benefits it could bring. Second part of education was a workshop, where the employees organized their own workstations following the 5S instructions learned from the theory-section.

The student project group thinks that training of the employees is considered the most important milestone of this project. The project members also believe that the training of the employees is a significant promote towards the Lean-culture between employees and to add more "working discipline" at the company. When everyone is trained to the principles of the 5S, everyone knows the rules and what 5S stands for. The project members believe that this also helps to maintain the changes made at the worksite. (Tuomivaara & Laakko, 2020).

2 Legacy of TEHOJA-project

During the TEHOJA project, cooperation was established with 18 different companies in Northern Finland, and as a result of the project, an innovative platform for collaborative robotics was built for Oamk, which enabled the construction of products and applications for companies. Totally, 42 products were developed in the TEHOJA project's product development projects were implemented. The original goal of the project was to implement only 10 pieces of the developed products. Perhaps the most successful robotic projects were carried out for the world's northernmost ceramics factory, Posio. The factory wanted to participate in the project to promote the ergonomics and resilience and well-being of its employees at work.

As a result of the TEHOJA project, several different projects have started in OAUS's mechanical engineering department: Potkua, Roboreel, Roboboost, Roboedu and Kotu projects. The TEHOJA project also contributed to the employment of more than 10 students in local companies, e.g. JMC Engine Oy, Sähkö-Rantek Oy and Pentik Oy.

From 2018, even more local SME's and all the rest of OUAS's mechanical engineering departments projects also started to participate in MEPE to deepen cooperation (see Table 1). Like the TEHOJA project, other projects work in cooperation with the business community in the area and implement various projects. Most of the new projects will further enhance the competitiveness of companies, by design new products, increase the efficiency of production mainly via Lean philosophy and the introduction of interoperable robots' capabilities to the local companies, as in the TEHOJA project. As a conclusion MEPE has widely risen' SME's interest to cooperation and awareness of OUAS's mechanical engineering education in Northern Finland. (Autio, 2020).

Table 1. Number of companies participating in MEPE and project cases between 2016-2020

Year	Companies	Number of project cases
2016	10	10
2017	12	17
2018	22	50
2019	20	53
2020	17	34

4.1 Concept of the MEPE inspires

The implementation of business experiments and the teaching of collaborative robotics, as well as experimentation in companies in the area, have been integrated into basic education thanks to the project. Operations will be continued if there is sufficient demand and need for expertise. The MEPE impacts has also been identified in other OUAS collaboration educational vocational institutions (called 6Aika) as a best practice to follow. They have been told the purpose of the project and the operating principle of the business experiments, but the same operating principles are not possible in all educational institutions, as they are vocational training institutions and do not have the same capabilities as a polytechnic (Autio, 2020).

3 Conclusion

The purpose of this paper was to present the MEPE approach developed by the School of Engineering and Natural Resources at Oulu University of Applied Sciences, in which the needs of local companies for the development of their operations have been harnessed to support the Schools mechanical engineering training.

Ideally, students would look for internships in companies themselves and complete the course very independently. However, the project topics defined in advance by the teaching staff in cooperation with the companies enable the ambitions of both parties to be realized. In teaching practical skills in product development and project management, such a lecture-like, independent way of studying may not produce results when the goal is to train engineers who know practical skills. Thus, there is a need for learning through motivation on a motivating topic and in an environment that matches the work tasks of a graduate mechanical engineer.

The aim of higher education institutions is to train engineers and to develop the professional identity of graduates of the engineering profession through class-room education (science) and the real-life development projects (application). Therefore, as an educator, the School of Engineering and Natural Resources promote our students' self-confidence and thus employment, when the step from student life to working life is not too wide a leap when they have during their study completed real-life industry projects. For many engineering students, this first step in their engineering career and experience working as an engineer can be a project internship or product development course where project topics are mostly given in MEPE and those handle every day, even business-critical challenges for real companies, but tailored to suit graduate engineering engineers. The job of a mechanical engineer is dealing with real world problems and it is best learned by doing, searching or asking for advice from the more experienced, and ultimately through experience. For this reason, each project work and product development course are supervised by an experienced lecturer who has worked in the industry for several years. As an experienced engineering professional, a lecturer can guide, consider potential risks and act as a mentor for engineering students starting their careers and working on a project, both in terms of project management and task development work. When supervising students, lecturers also get to see the activities of local companies and expand their view of the needs of companies and areas for development. This enables the continuous development of educational content and the emergence of new project ideas that would be better able to serve local companies, e.g., providing a low-risk opportunity to test the impact of robotics and other new technologies on a company's production.

This collaboration with companies and integrating their needs into the training of mechanical engineers underscores the fact that the university of applied sciences is a university for working life and industry. By supporting the growth of the professional identity of our engineering students, training them in cooperation with working life and utilizing the know-how of our experienced lecturers in guidance, we strongly contribute to the success of companies in the region by providing experts who meet the needs of the labor market.

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Oamk_Highway – New route for young people towards engineering degree in Northern Finland

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Abstract

The Finland higher education (HE) system is based on the dual system with the Universities and with the Polytechnics also known as Universities of Applied Sciences (UAS). The students pursuing for HE admission can have various routes to acquire their right to study in the Universities or in the UAS's. These options can be e.g., official entrance exams or by the evaluation of grades from the vocational or high school diploma. Oulu University of Applied Sciences (OUAS) is in the northern Finland, in the city of Oulu. OUAS has c.a. 9500 students and around 500 staff members. The School of Engineering and Natural Resources as c.a. 2400 students, and c.a. 150 staff members. This paper introduces a new pathway by the OUAS School of Engineering and Natural Resources to acquire new engineering students from the vocational and high school level in Northern Finland. This is called Oamk_Highway, in which the students in the vocational or high school studies 15 credit points of specified OUAS HE studies, and together with the vocational of high school degree diploma, the student will get direct admission to engineering degrees in the OUAS. The 15 ECTS constitutes from mathematics (5 ECTS), physics (5 ECTS) and engineering degree subject matter studies (5 ECTS), which can be freely selected by the student from the list of specified Oamk_Highway courses. The courses are mainly organized by online course and are taught by the OUAS teachers (Senior lecturers or Principal lecturers), however, the mathematics course is organized locally and taught in the high school or in the vocation school by using the materials, exams and support provided by the OUAS. There are totally 5 engineering degrees available for the students to choose from after admission via the Highway concept. These degrees are: Mechanical Engineering degree, Building Services Engineering degree, Electrical and Automation Engineering degree, Energy and Environmental Engineering degree, Construction and Civil Engineering degree.

Keywords: Continuous learning; Engineering Education; Pathway; Higher education

1 Introduction

The continuous learning is one of the most important strategic guidelines to ensure Finland's future success in higher education. The strategic guidelines have forced universities to develop new ways to support non-degree-oriented education, develop new pathways to higher education and prepare students for working life more quickly. All these goals have supported by the funding model of universities. It has also been agreed in the funding agreements of higher education institutions that higher education institutions will increase their co-operation with the high schools and vocational institutions in order to speed up the young people's transition to higher education. According to Finnish High School Law (2019), students need to have the opportunity to get acquainted various fields and the skills required for studies in higher education during high school studies. A glimpse into higher education facilitates the choice of field and provides information on requirements needed in higher education. (Finnish Ministry of Education and Culture 2019.)

Higher education (HE) system in Finland is based on the dual system with the Universities and with the Polytechnics also known as Universities of Applied Sciences (UAS). (Figure 1) The universities conduct scientific research and the scientific bachelor, master and doctoral degrees. UAS task is to teach and conduct development projects that meet the needs of working life. Studying the Bachelor degree at the UAS lasts from 3.5 to 4.5 years. The Master degree can be completed after two years of work experience.

The students pursuing for HE admission can have various routes to acquire their right to study in the Universities or in the UAS. After comprehensive school adolescents can apply to secondary education: general upper secondary schools (later called high schools) or vocational institutions. The secondary education is free of charge. High schools provide general education and in the end of studies students have matriculation examinations. The vocational institutions provide basic skills in professional qualifications and occupations.

After secondary education students can apply to study right to university or UAS by official entrance exams or by the evaluation of grades from the vocational or high school diploma. (Figure 1.)

In the field the engineering, universities are competing for new students and thinking new ways to get students. In northern Finland, new engineers will still be needed in the coming years to replace the engineering workforce which is retiring, also the digitalization that is emerging in all fields of engineering requires new engineering approaches to many business areas.

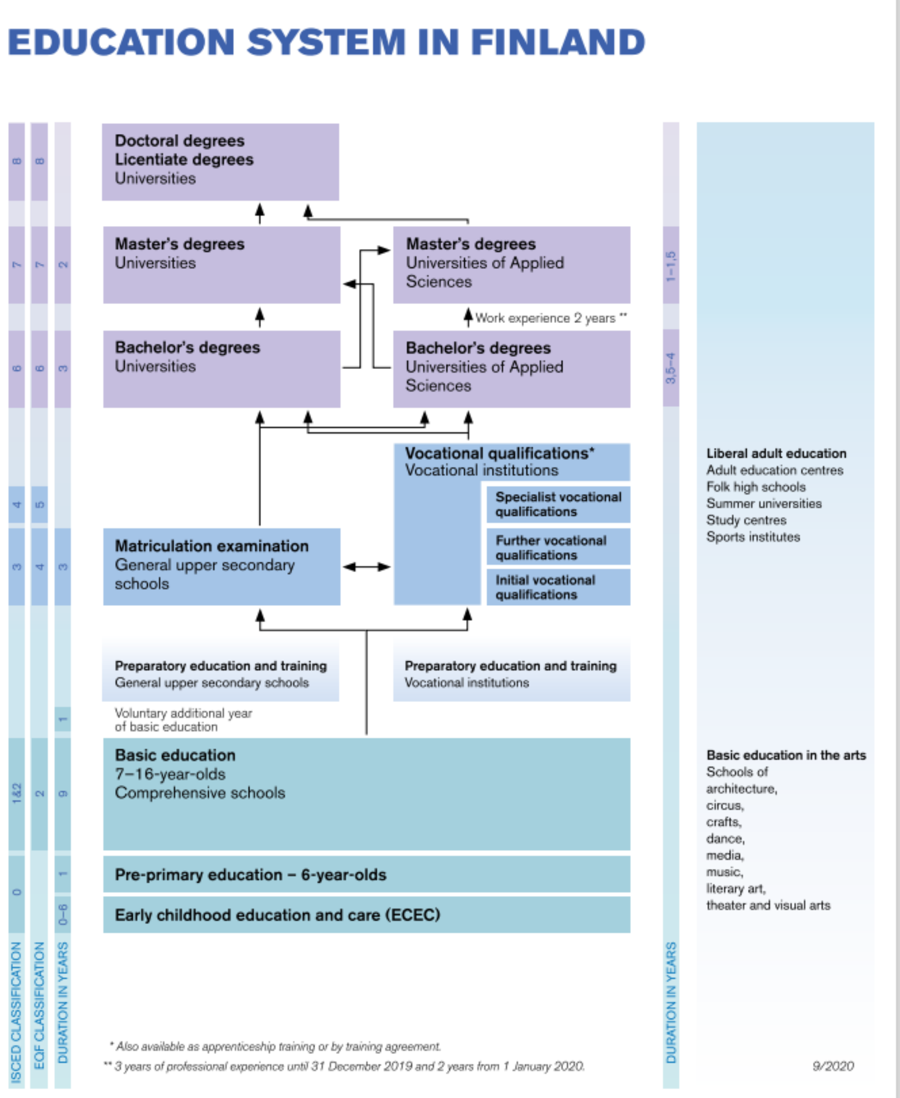

Figure 1. The Finnish Education System: Dual Model (Ministry of Education and Culture, Finland 2021.)

2 Aim

This paper introduces a new pathway by the Oulu UAS School of Engineering and Natural Resources to acquire new engineering students from the vocational and high school level in Northern Finland. We discuss the concept, deployment and early findings of the new approach in following chapters. Firstly, we discuss the research approach (method) for design, development and piloting of the Oamk_Highway model. Then in the following chapter we discuss the early results of the new pathway, and we conclude by discussion and conclusions chapters.

3 Methods

3.1 Design

A descriptive study design was used to describe the development and piloting of the new pathway for young people towards in engineering degree in Northern Finland.

3.2 Development

Oamk_Highway is a new pathway from the vocational and high school level to higher education (university of applied sciences) developed by the Oulu University of Applied Sciences (OUAS), School of Engineering and Natural Resources. OUAS is located in the northern Finland, in the city of Oulu. It has c.a. 9500 students and 500 staff members. The School of Engineering and Natural Resources as c.a. 2400 students, and c.a. 150 staff members.

The aim of a pathway development was to acquire new engineering students and to shorten education paths and speed up the transition from education to working life. The new pathway was developed in close collaboration the vocational institutions and high schools. Teachers in the field of mathematics, physics and engineering from vocational and high schools and university of applied sciences compared the curricula of vocational, high school and higher education levels. The similarities in the field of mathematics and physics were found. Based on that the new pathway from vocational and high schools to university of applied sciences were designed. The student recruitment process for pathway was developed in collaboration with experts of student counsellors and student services.

In the Oamk_Highway the students in the vocational or high school study 15 credit points of specified OUAS higher education studies, and together with the vocational or high school degree diploma, the student will get direct admission to engineering degrees in the OUAS. The 15 credit points includes mathematics (5 ECTS), physics (5 ECTS) and engineering degree subject matter studies (5 ECTS) that can be freely selected by the student from the list of specified Oamk_Highway courses. The courses are mainly organized by online course and are taught by the OUAS teachers (Senior lecturers or Principal lecturers). However, the mathematics course is organized locally and taught in the high school or in the vocation institution by using the materials, exams and support provided by the OUAS. There are totally 5 engineering degrees available for the students to choose from after admission via the Oamk_Highway. These degrees are: Mechanical Engineering degree, Building Services Engineering degree, Electrical and Automation Engineering degree, Energy and Environmental Engineering degree, Construction and Civil Engineering degree.

The recommendation is to start studying for a mathematics course (5 ECTS) that will give the student sufficient skills to complete the course for others. Engineering is mainly based on mathematical materials. Studying mathematics in high school makes it easier to cope with mathematics at the University of Applied Sciences. A student at a vocational school, on the other hand, can study the additional courses offered and thus make it easier for them to cope at the University of Applied Sciences.

Since studying physics requires a certain level of mathematical competence, it has been agreed that physics (5 ECTS) will be completed after a course in mathematics. The goal of the first course in physics is to develop the student's mathematical, engineering-like mindset, which is a very important skill for later studies. The themes of physics mainly deal with mechanics and thermal science with tasks related to the field of technology. The physics studies in vocational institutions and high schools meets the objectives of the first physics course in OUAS.

The purpose of the engineering courses is to provide basic information on studies in the field. The student can choose one course (5 ECTS) in energy technology, building technology, mechanical engineering or building technology. The course served as an introduction type or "sneak-peek course" for higher engineering field education. This means that students can get to know higher education during secondary education, and their selection can be based on their interest for a specific engineering field.

Once the student has completed the entire Oamk_Highway studies (15 ECTS) and completed a secondary degree, the student will get direct admission to engineering degrees in the OUAS. The admission needs to be requested via the spring semester annual application process to HE which is organized in Finland via central national level application system called Opintopolku (www.opintopolku.fi) . The application process is organized via special admission track.

3.3 Piloting

Oamk_Highway pilot started in August 2020. The students from six high schools and two vocational institutions in Northern Finland were invited to participated in the pilot. The institutions were chosen based on their location and interest. All the selected high schools and vocational schools locate in Northern Finland and less than 200 km from OUAS Linnanmaa Campus. Also, strategic partnerships with regional large vocational schools such as OSAO and JEDU impacted the selection. For example, OUAS has a long cooperation with Educational Consortium OSAO (Oulu), so they were chosen because of the cooperation pattern. In student recruitment, co-operation was established with the staff of the partner high schools and vocational institutions. In addition, Oamk_Highway sparked interest in the news and got a lot of publicity through it. The eligibility criteria for the participants were as follows: studying in high school or vocational institution on the semester when the pilot started, studies have progressed as planned in the curriculum at least one year, the basics of mathematics have progressed.

Before starting the pilot, an online meeting was held with each pilot partners' school principal, study counselors and teacher of mathematics and physics. The aim was to engage the institutions and go through all the necessary information needed to counsel the students to apply and progress in the Oamk_Highway.

The application for Oamk_Highway and Frequently Asked Questions (FAQ) took place on the website (www.oamk.fi/highway) and all eligibility criteria fulfilled participants were sent the acceptance letter by email and guides to the sign in the Moodle online learning environment. After signing the Moodle, the students were able to start their studies regardless of time and place. The studies were recommended to start in mathematics to get routine to count more difficult studies. All guides for studying and all courses were in online learning environment. The tutor helped students in online learning environment if needed. After passing studies in Oamk_Highway, the student will get a diploma from OUAS that is needed to apply to OUAS.

4 Results

A total of 93 students started in pilot. 83 % (n=78) them were men and 17 % (n=15) women. 23 % (n=21) were from high school and 77 % (n=72) from vocational institutions.

Total of 255 ECTS were completed between September 2020 and May 2021. The semester continues until end of May. The average of completed studies was 3 ECTS per student. The results of completed courses are shown in Table 1.

In spring 2021, a total of 9 Oamk_Highway students who completed the Oamk_Highway path applied to Oamk, and they applied for a study-place in OUAS.

Table 1. Completed courses between September 2020 and May 2021 (the results updated 05/2021)

	Started the course % (n)	Completed the course % (n)	Ongoing
Mathematics	25% (23)	96% (22)	4% (1)
Physics	26% (24)	54% (13)	46% (11)
Oamk_Highway – module (Selected Engineering Degree Course)	100% (93)	18% (17)	82% (76)

5 Discussion

The new pathway opens a faster and easier route for students to apply to the university and at the same time utilizes the knowledge learned at the secondary education. For students, the pathway also opens a faster route to study and graduation with HE degree. It also gives the student the opportunity to get acquainted with university studies already during the second year and at the same time see the level of requirements for university studies. An important consideration is also that the student may find in the second degree that college studies are not the right route for them.

Through Oamk_Highway, OAUS gets new, motivated students who have already committed to the university during their secondary education. OUAS can reduce the number of students coming through regular annual entrance exams and at the same time raise funding for its own activities through continuous learning points which are credited by the Finland Ministry of Education funding model for HE.

Students will always give feedback after the completion of Oamk_Highway studies. They will be asked about the progress, completion and development issues of the studies. This data provides an opportunity to examine factors affected in higher education. Oamk_Highway will also open the door to other co-operation with secondary education schools and institutions.

The number of girls (17%) in the first-year pilot is low and the goal is to increase this number as well. In the marketing of Oamk Highway, schools have also emphasized the possibility for girls to participate in education. OAUS is also coordinating the Girls and Technology -project, which has 9th graders in the main target group. In addition, girls' interest in technology has been strongly marketed on social media.

The success of Oamk_Highway requires close cooperation between the university and the secondary school. Commitment to collaboration is needed from management, study counselors, and teachers of mathematics and physics. In addition, communication between mathematics and physics teachers is important because teachers in secondary education see the level of requirements of higher education and gain new practical ideas for their own teaching. In these discussions, it has also been estimated that Oamk_Highway brings more motivation to study at the 2nd degree and may increase the study of mathematics at the secondary level. Also, the collaboration by the Vocation Schools and High Schools with OUAS can be important factor when young students are considering their selection for High School or Vocational School because the strategic partnership with OUAS brings direct admission possibility via Oamk_Highway to their students, which offers them competitive advantage over other vocational schools or high schools.

6 Conclusion

Oamk_Highway is a new pathway for students from the vocational and high school level to higher education Bachelor level engineering degree studies developed by the Oulu University of Applied Sciences (OUAS) School of Engineering and Natural Resources. The new pathway project has been introduced as a pilot project to selected High Schools and Vocational Schools in Norther Finland.

The early findings from the discussion with the High School and Vocational School representatives, and application results of students to Highway studies as presented the results chapter, suggest that Oamk_Highway is considered as feasible concept for a new type of pathway towards engineering degrees. The pilot approach and the value offered by the Highway studies are perceived as highly attractive both from the High Schools and Vocational Schools point of view, and most importantly, the pilot is well received by the students as its builds direct linkage to acquiring admission to OUAS engineering degree programs. The admission can be required by completing the pre-defined Oamk_Highway courses during the High School or Vocational School study, and thus e.g., the pressure of the spring semester admission exams can be avoided by the students as they have already secured their engineering degree program admission to OUAS.

We plan to continue to observe the progress of Oamk_Highway for coming years as the pilot project progresses forward, and we get more direct student feedback from their studies. Also, in the pilot stage all the Highway -courses were traditional classroom courses or online courses, but new learning approaches will be used in the future. Our vision is to establish Oamk_Highway as recognized and well-known concept for student towards engineering degree in Northern Finland and improve the timely graduation of engineering students.

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How to engage engineering students to Physics: A case report of an Introductory Physics course taught in the first year of an Engineering programme

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Abstract

Lecturers who teach Introductory Physics courses to engineering students face several challenges. Besides the usually high number of students (> 100), there is a preconception in considering the contents of physics courses very complex. These aspects, together with the fact that enrolment is required for an engineering study plan, make physics a course with low student engagement. This paper describes strategies and activities implemented in an Introductory Physics course (Physics EE), for first-year students of Industrial Electronics and Computers Engineering (Integrated Master) at the University of Minho to increase students' motivation, engagement and active learning. The implemented strategy includes: sharing the learning outcomes at the beginning of each lesson to help and guide students to successfully complete the tasks related to the topic and study more effectively; regular use of Audience Response Systems to encourage participation and give immediate feedback; use of in-class exercises to promote critical thinking and cooperation in the discussion of complex concepts; two-stage assessment (individual test followed by a similar test in groups), to promote collaborative learning and immediate feedback. These approaches took place during the 2018/2019 academic year in face-to-face teaching and in the 2019/2020 academic year in online teaching, due to the COVID-19 pandemic. In both semesters, the students' perceptions of the implemented changes were collected through anonymous questionnaires during the semester and at the end of term. The results indicate that, for both semesters, the students were satisfied with the implemented changes; they recognised the value of the immediate effective feedback to improve their learning experience and revealed high levels of satisfaction with the classes. These findings are consistent among students who attended face-to-face and online classes, and among students from different disciplinary areas, suggesting that the implementation of active learning strategies in this physics course may be transferable to different teaching contexts and scientific areas.

Keywords: Introductory Physics; Students Engagement; Active Learning; Collaborative Learning; Audience Response Systems (ARS).

1 Introduction

Teaching a specific course from a disciplinary area not directly related to the programme is challenging. Students tend to focus more on courses directly related to the area of the programme due to their higher personal affinity to these subjects. Therefore, the intrinsic motivation of students is low (Zavala et al., 2015), which leads to a lack of engagement in the activities of the course. This situation can be aggravated when a large number of students are enrolled and when the subject is regarded as complex by them. A typical example is Introductory Physics in science, technology, engineering and mathematics (STEM) programmes (Redish, 1994), many of them not directly related with Physics in terms of content. In addition, these courses are usually taught to a large number of students from different programmes.

Extensive research has demonstrated the effectiveness of active learning approaches in promoting students' engagement in STEM programmes (*e.g.*, Freeman et al., 2014; Hake, 1998; Prince, 2004), in particular in Introductory Physics courses (Meltzer & Thornton, 2012). Such evidence makes the use of active learning activities adequate to the present case. Active learning is a broad concept that can be defined as an interactive student-centred instructional approach that encourages students to be active and engaged in their learning process by performing meaningful activities and by thinking critically about them (Bonwell & Eison, 1991, Hernández-de-Menéndez et al., 2019; Prince, 2004). The literature offers an extensive menu of active learning activities, from short or simple activities (*e.g.*, questions and answers) to longer and most complex ones (*e.g.*, team-based learning), which can be performed individually (*e.g.*, one-minute paper), in small groups (*e.g.*, debates) or large groups (*e.g.*, quizzes using Audience Response Systems; ARS; Hernández-de-Menéndez et al., 2019; Prince & Felder 2007). To be effective, these activities must be designed around relevant learning outcomes that express the understanding of the important knowledge and skills to be learned (Prince, 2004) and feedback and support must be provided throughout the process (Yadav et al., 2011).

The benefits of active learning are well documented in the literature, with several studies showing its positive relationship with students' motivation, satisfaction, lecture attendance, engagement with learning (Deslauriers et al., 2019; Hernández-de-Menéndez et al., 2019; Prince, 2004), and with the acquisition of essential skills such as teamwork, communication, autonomy, responsibility, self-regulation, critical thinking and problem-solving (Hernández-de-Menéndez et al., 2019; Prince, 2004). The latter constitute higher-order thinking skills (HOTS), which are particularly relevant in engineering education (Asok et al., 2016; Hernández-de-Menéndez et al., 2019). Research also found evidence that active learning improves students' overall academic performance in STEM courses compared to traditional lecturing, in particular students developed a better understanding of abstract physics concepts (Freeman et al., 2014), scored higher in conceptual inventory tests (Deslauriers et al., 2019; Hake, 1998) and were less likely to fail (Freeman et al., 2014).

Despite all the evidence of success, many students still consider the lecturing classes more effective and prefer to stay in their comfort zone, resisting being actively engaged in their learning process (Deslauriers et al., 2019). Therefore, to enhance the success of active learning, both parties must understand its nature, experience its value and accept that active learning leads to deeper learning. Teachers play an important role in promoting active learning, explaining this learning approach to students, engaging them in relevant activities and sharing timely feedback that maximizes their learning potential.

Based on these principles, the present case describes active learning strategies and activities implemented in an Introductory Physics course for first-year students of Industrial Electronics and Computers Engineering (Integrated Master) at the University of Minho, to increase their motivation, engagement, and active learning. It also reports the students' perceptions of their learning experience. The paper is organised as follows: after a brief description of the course, details of the implemented approaches are presented, followed by the description of the methods used to collect student perceptions. Then, the obtained results are analysed, and discussed and the general conclusions of this case study are presented.

2 Case Report Context

The reported approaches took place during the 2018/2019 academic year in face-to-face teaching and in the 2019/2020 academic year in online teaching due to the COVID-19 pandemic.

2.1 Course Description

The Curricular Unit (CU), Physics EE, required for all the students enrolled in the Integrated Masters in Engineering, covers the fields of Mechanics and Waves. The CU is organised in lecture, or theoretical, classes (2 h/week), taught simultaneously for all the students, and theory-practice classes (2h/week), where the students are divided into classes of 35-40 students each. The CU is taught in the second semester of the integrated master for 15 weeks, and attendance is not mandatory. In 2018/2019, approximately 67 % of the students were enrolled in the CU for the first time and in 2019/2020, the value was approximately 63 %. The remaining students did not have success in the previous academic year. The number of students and the distribution according to gender is presented in Table 1.

Table 1. Distribution of the students enrolled in the curricular unit Physics EE by the academic years under study and by sex.

Academic year	Nº of students	Female	Male
2018/2019	126	18 (14.3 %)	108 (85.7 %)
2019/2020	132	16 (12.1 %)	116 (87.9 %)

3 Implemented Approaches

The first day of class is intended to be one of the most important classes of all the semester (Davis, 2009) since it is the moment when the students know the teacher, discuss the teaching and learning approaches, the evaluation criteria and create expectations about the course. How the semester will run in terms of teaching, learning and the relationship teacher-student will largely depend on this first moment. It is also important for the teacher to know the expectations of their students towards the CU, before starting the classes, especially in a course with so many students, where it is almost impossible to have a conversation with every single student. To overcome this problem, students enrolled in the CU were invited, one week before the first class, to answer an anonymous questionnaire about their expectations towards the CU. The analysis of the questionnaire gave important tips on the students' expectations, helping to design the first day of classes and to present the strategies and active learning activities that would be implemented throughout the semester.

It is also important that students be aware, in advance, of the proposals for the assessment, the teaching and learning methodologies, and be actively involved in their analysis, discussion and adjustment, if necessary. For this reason, one week before the beginning of the semester, the teacher shared with students in the e-learning platform available at the University of Minho, detailed information about the assessment proposals, the methodologies to be adopted in class, and a plan of all teaching and assessment activities.

The theoretical lessons of 2018/2019 were taught using PowerPoints and, whenever possible, some experimental demonstrations with homemade resources were used as well as interactive simulations available on the internet. At the beginning of each class, students received explicit information about the sessions' learning outcomes, to clarify the purpose of the activities to be performed and their relation to the knowledge and skills to be learned. Students' understanding of the learning outcomes and their connection to the learning activities is essential to encourage their engagement and guide them during tasks (Prince, 2004).

Throughout classes, active learning strategies were implemented to increase students' interest, motivation, and commitment in classes and to promote their active learning attitude and practice. The traditional lecturing activity was reduced, and multiple active learning activities were interspersed in classes, such as ARS, think-pair-share, in-class exercises and two-stage assessment.

Audience Response Systems were used regularly during the semester to encourage students' participation and engagement in classes and to obtain and give immediate feedback (Gousseau et al. 2016). Students could use their smartphones to anonymously answer multiple types of questions (memory, conceptual, application, open-ended), combining different degrees of complexity. One of the advantages of these systems is that they allow the teacher to adapt, in real-time, the pedagogical strategies and activities.

Students were engaged in debates and "think-pair-share" activities to evaluate their level of understanding of the content, to promote critical thinking, and to obtain and give immediate feedback, At the end of each lesson, questions were used to assess the student's understanding of the key concept(s) or to identify misconceptions to be clarified at that moment, or eventually, in the next class.

In-class exercises were employed in theory-practice classes and in some lecturing classes when appropriate to focus student's attention on interpretation and analysis, to promote critical thinking and cooperation in the discussion of complex concepts, and to co-create solutions. Students worked in informal groups, and during the group discussion, they were asked to explain to the class their qualitative reasoning. When misconceptions were identified by the teacher in a given group, they were addressed to the whole class. In this way, the dialogue between student-student and student-teacher was promoted as well as the student's engagement towards the course.

A two-stage assessment was applied in this course for the first time in the academic year of 2018/2019 to promote collaborative learning and to obtain and give immediate feedback. In the two-stage assessment, students firstly completed an individual test for 70 minutes. Afterwards, in groups of 3 or 4 students, previously organised by the students themselves, they solved a group test for 40 minutes. The individual test was composed of multiple-choice questions, requiring justification of the chosen options and of the application problems. The group test had questions similar to those of the individual test. Students had to reach a consensus on their answer since only a single test-answer sheet was delivered to the group. The two-stage tests transformed the assessment moment into a learning experience, promoted collaborative work and peer instruction, and offered immediate feedback as a result of the discussion with pairs. It also contributed to increasing students' motivation and engagement over the semester, as reported by others (Rieger & Heine, 2014). In determining the final test grade for each student, a weighting of 85% and 15% for the individual and the group test respectively was used. Students were previously informed that if the group score was lower than the individual test grade, the group test score would be excluded in calculating the final test grade.

During the academic year 2019/2020, due to the suspension of face-to-face classes, the course was delivered online, combining synchronous and asynchronous modes, therefore some changes were implemented relative to the approach of the previous academic year. One week before each synchronous session, all the support materials for the session, comprising annotated PowerPoints with voice narration, challenging problems, to encourage the debate during online class, and pre-readings indications notes, were disseminated through the e-learning platform. With this kind of "flipped classroom", the synchronous session was converted into an open discussion, where students could ask questions to clarify their doubts. In these sessions, the use of ARS was done in the same way as in face-to-face classes.

The assessment method was also changed since it was not possible to have physical working groups and the two-stage assessment was not suitable for an online environment. Considering the importance of collaborative learning and team working, the elaboration of a small project in groups of 4 students was proposed, using the Padlet platform, and also an individual online test at the end of the semester. The project, equal for all the groups, was related to the physical concepts underlying the operation of the Bom Jesus do Monte funicular (https://en.wikipedia.org/wiki/Bom_Jesus_do_Monte_Funicular).

4 Methods

Evidence of students' expectations and perceptions was collected, in both academic years, throughout and at the end of the semester, using anonymous questionnaires that included both quantitative and qualitative data to obtain the broadest picture of students' reactions. The questionnaire about their expectations towards the CU included three dimensions: (i) Perceptions about the demand and importance of the CU; (ii) Students' attitudes towards classes; (iii) Use of mobile phones in teaching activities. Students' perceptions of the two stage-assessment were collected, during the academic year 2018/2019, after the first assessment, through a questionnaire that included four open-ended questions about the positive and negative aspects of this type of evaluation; recommendations to the colleagues who chose to solve only the individual test; and other free comments/suggestions about this type of assessment. To assess the students' perceptions and satisfaction with the applied methodologies and the pedagogical dimension of the use of ARS, students were invited to answer an anonymous questionnaire at the end of each semester. Closed questions with statements were used and the students rated them according to their degree of agreement, using a 7-point Likert scale (1- Strongly Disagree; 7 - Strongly Agree). At the end of the questionnaire, the students were asked to express their opinions regarding the most positive aspects of the performed activities and suggestions for improvement. Informal conversations with students during or after lessons were also important to determine whether the implemented approaches were working. The results were used to make adjustments in the pedagogical strategy and activities throughout the semester.

5 Students' Perceptions

5.1 Expectation toward the curricular unit

Around 64% and 45% of the students enrolled in the CU in the academic years of 2018/2019 and 2019/2020, respectively, answered a first questionnaire about their expectations towards the CU. For both academic years, the great majority of the students (around 70%) considered the CU to be demanding, but they also recognised the importance of the CU for their course. Regarding their attitudes towards the classes, although the presence was not mandatory, around 68% of the students considered class attendance as an obligation, in the sense that they feel that they need to attend the classes, but only 30% used to have an active participation during classes.

5.2 Two stage-assessment

Eighty-nine out of the 106 students that attended the first test have done a two stage-assessment, and 46 (52%) students have answered the questionnaire. All students, except two, recommend the two stage-assessment. Concerning the positive aspects, most students referred to the collaborative work provided during the test and the immediate feedback obtained from the interaction with their group mates that emerged during the second stage of the assessment. Besides this, it was interesting to note some other quotes:

"Similarity with the individual test and equivalent degree of difficulty." (student A)

"I met new people. I didn't know the students in my group." (student B)

"The second opportunity to solve problems already proposed individually, now with higher coolness and *conscience."* (student C)

As a less positive aspect, most of the students indicated the duration of the second part of the test since the time was limited to discuss and reach a consensus on the answers. Increasing the time for the group test was the main recommendation given in the qualitative responses.

5.3 Use of audience response systems

A total of 44 (34,9%) students in 2018/2019 and 80 (60,6%) students in 2019/2020 returned the questionnaire. In Figure 1, the average value obtained is compared for the following statements:

- Statement 1 – "It allowed me to have immediate feedback."
- Statement 2 - "My participation in these classes/sessions has improved."
- Statement 3 - "It facilitated my learning."
- Statement 4 - "It prepared me better for the assessment."
- Statement 5 - "It allowed me to better assess whether I understood the subjects."

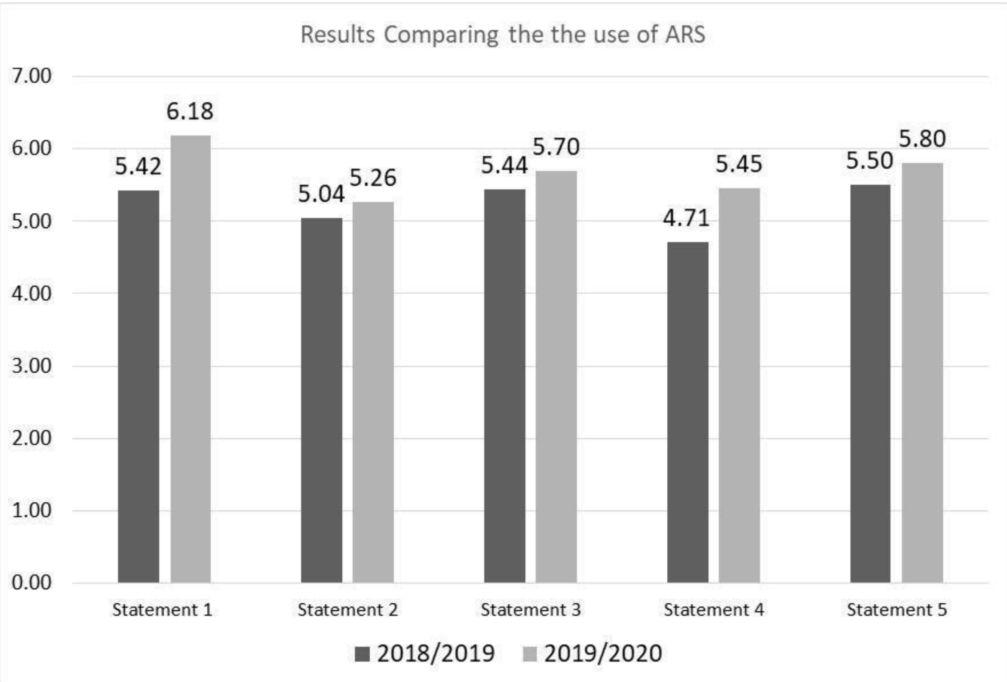

Figure 1. Comparison of average results for ARS statements.

Also interesting were the most mentioned positive aspects in the open-ended questions of the questionnaire, list in table 2.

Table 2. Comparison of students' feedback on the use of ARS in open-ended questions.

Positive Aspects	2018/2019	2019/2020
Understanding/consolidation of course contents	25.0%	27.5%
Improves/increases student-teacher interactivity	28.0%	25.0%

These results clearly indicate the good acceptance of ARS by the students, which correlates with their opinions regarding improvements. In fact, the great majority of students pointed out "*nothing to change*" and few students mentioned:" *increase the response time*" and also "*trying to control the noise during discussion*".

5.4 Students' final comments on the implemented approaches

Most of the students were satisfied with the implemented strategies and activities. Among the positive comments collected in the anonymous questionnaire distributed by the teacher, students have highlighted the students-teacher interaction, the learning environment, the teamwork and the variety of learning tasks. They also mentioned that the course was well structured and organised. In response to the anonymous CU survey, implemented at the end of each semester by the University of Minho's Internal System of Quality Assurance, students commented that they enjoyed the course and the implemented approaches, and highlighted the two-stage assessment and the ARS activities. Students have also identified some aspects to be improved, most of them related to the increase in time for the completion of some tasks.

6 Discussion

According to the results of the student's expectations toward the CU, specifically regarding the low percentage of active participation in classes (30%), it is important to explain the value of the proposed activities for the classes, and establish expectations for students' engagement and reinforce them throughout the term. It is also important to communicate, focus on the learning outcomes and what students will be able to achieve at the end of the course.

The students' perceptions about the implemented approaches in this CU in both academic years are positive, in general. The feedback and the collaborative work, as well as the deeper understanding achieved during the group discussion in the two-stage assessment, were the most important gains referred by the students, which are in line with the literature (Gilley & Clarkston 2014; Wieman et al. 2014). Even if the duration of the group test was one of the negative aspects reported by the students, they felt more motivated and less stressed. It was found that the final group score was equal to or better than the individual score for almost all the students. This was also one of the aspects that contributed to the students' motivation and engagement towards the CU.

According to Hassanin et al. (2016), the use of ARS, in an anonymous way, removes any inhibitions or embarrassment, allowing the students to become active participants during classes and increase their engagement and learning. It also provided the teacher real-time information about the achievement of learning outcomes planned for the lesson, allowing, if necessary, adjustments to the lesson plan. The results indicated that the students, in face-to-face and online classes, had positive perceptions of the use of ARS as reported in the literature (Christianson, 2020). In addition, most of the students reported that the technology improved the students-teacher interactivity and helped them understand course subjects.

The analysis of students' perceptions was based on data collected from self-reported surveys, relying on their ability to adequately self-report the lived experience. However, self-report is subject to biases that may affect the validity of the results (Podsakoff et al., 2003). The combination of observation with methods of collecting quantitative and qualitative data will allow obtaining in-depth information from multiple sources and increase the understanding of the students' experiences.

The continuation of the application of active learning strategies and activities to the Introductory Physics course suggests the development of metrics to systematically measure active learning results in students' satisfaction and engagement and academic performance (*e.g.*, conceptual inventory tests; final grades, pass rates).

7 Conclusion

This study reports the use of active learning strategies and activities to increase students' engagement and motivation in a large Introductory Physics course for engineering students. This study also presents some results of students' perceptions towards the implemented approaches during the 2018/2019 academic year in face-to-face teaching and the 2019/2020 academic year in online teaching. The strategies and activities proved to be adequate, regardless of the type of the lessons, to achieve important goals in the learning process: motivation, participation and engagement of students in a course with a high number of students (>100), often perceived as difficult and demanding. Interestingly, the students' perceptions and comments about the experience, namely in ARS (Figure 1), were similar in both analysed academic years (the pre-lockdown 2018/2019 and during the lockdown in 2019/2020), suggesting that active learning strategies are beneficial for learning both in face-to-face and online teaching.

Students who are accustomed to traditional lectures may need time to adjust to active learning methodologies. The same applies to teachers, the planning and the preparation for these strategies need considerable dedication at first. However, once getting familiar with the approaches and technologies, activities become less time demanding without losing the strength in engaging and challenging students so that they experience meaningful learning.

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Students' perceptions of the use of traditional methods and active learning strategies in the classroom: findings from a case study

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Abstract

This paper reports on findings from a case study based on students' perceptions of the use of traditional methods and active learning in the context of a specific curricular unit in Higher Education. The high levels of absenteeism in class, the lack of interest by the students and the assessment results were some of the main reasons that lead the course lecturer to implement a set of changes in the curricular unit, in the following academic year. These changes included the use of traditional and non-traditional teaching and assessment practices in the classroom such as flipped classroom, team-based learning, brainstorming, lectures, demonstration, gallery walk, review of videos and case studies. To evaluate student satisfaction with these changes, feedback was collected from students, at the end of the semester, through a questionnaire with 26 questions on a five-level Likert scale. The topics addressed in the questionnaire included the following dimensions: teacher performance, teaching and assessment methods, competences development and overall satisfaction with the curricular unit. The participants in the study were 94 students enrolled in the curricular unit of "Management Information Systems", which is part of the 3rd year study plan of the Management degree programme at Portucalense University, Porto, Portugal. This curricular unit is mandatory and has more than one hundred students enrolled every year. The curricular unit has a weight of 5 ECTS and 45 contact hours. Findings from students' perceptions reveal a positive view of the changes implemented, as lectures were considered more interesting and there was more active engagement by the students. There was also found a positive relationship between students' opinion about the curricular unit and its importance for the development of student's skills and the application of knowledge in their future professional life.

Keywords: Higher Education, Active Learning, Management programme, students´ perceptions

1 Introduction

In the current economic context, usually described as one of globalization, constant change, and sharp disruptions caused by information technologies, new forms of employment require that non-technical skills be developed. Several studies by different entities (Teach Trends, 2019; Allen, 2020; The World Bank, 2019; OCDE, 2019) point to the need for workers with skills that cannot be replaced by robots, namely cognitive and socio-behavioural skills. In addition to, of course, digital skills, since any worker, now and in the future, will interact more and more with information technologies in their day-to-day activities (Laar, Dijk, Deursen & Haan, 2020).

In the recent past, people often spoke with enthusiasm about skills such as entrepreneurial spirit and creativity. Today, business innovation entails the need for interdisciplinarity. Workers are also required to have skills in collaborative work, communication and negotiation, empathy, and leadership (OCDE, 2019). They should demonstrate their ability to adapt to change and to learn throughout life. Critical thinking and the ability to identify problems, proactively create solutions to these problems, and make decisions in contexts of uncertainty, minimizing risks, are also increasingly valued in the current job market (Abelha, Fernandes, Mesquita, Seabra, & Ferreira-Oliveira, 2020).

Recent reports on the trends of teaching and learning methods in Higher Education refer that there has been a modest shift from traditional teacher-centered methods to more active learning strategies, which are student centered (Gaebel, Zhang, & Bunescu, 2018). Traditional methods include mostly lecture classes, where the teacher usually focuses on the use of slides to deliver the course content, with hardly no interaction or active engagement by the students. Meanwhile, active learning strategies focus on developing students' critical thinking, problem solving and teamwork skills by using a constructivist approach to teaching. Active learning strategies (Felder & Brent, 2006) can include a variety of methods and techniques, ranging from less complex techniques in terms of their duration and implementation, such as brainstorming, gallery walk, think-pair-share, video analysis, case solving, etc. to more complex and integrated approaches such as team-based learning, flipped classroom, project-based learning, etc (Fernandes, Flores, & Lima, 2012; Fernandes, Mesquita, Flores, & Lima, 2014; Lima et al., 2017). However, despite the intention for more student-active learning, teaching remains predominantly traditional and teacher-centred, with several barriers for active learning (Børte, Nesje, & Lillejord, 2020). For student active learning to succeed, Borte, Nesje and Lillejord (2020) identified the following prerequisites: (1) better alignment between research and teaching practices, (2) a supporting infrastructure for research and teaching, (3) staff professional development and learning designs.

Student assessment also differs in each one of these approaches, as the main curriculum elements (course contents, learning outcomes and assessment methods) are aligned with the pedagogical philosophy followed by the teacher (Brown & Hirschfeld, 2008; Segers & Dochy, 2006). Traditional teaching environments, on the one hand, focus on final examinations, that occur usually at the end of semester, with very few opportunities for feedback and discussion of the work developed by students. Active learning, on the other hand, promotes assessment for learning (Earl & Katz, 2006), where the purpose of assessment is mainly formative and aimed at improving student learning, by creating several opportunities for student feedback (from teachers, peers or external agents) and for monitoring student learning, providing students with a learning environment favourable to the development of critical thinking, teamwork and self-evaluation competences (Fernandes, Alves, & Uebe-Mansur, 2021; Flores et al., 2020; Pereira, Assunção Flores, & Barros, 2017).

This study aims to analyse a case study that took place in a curricular unit from a Management degree programme at Portucalense University (UPT), Portugal. It is private university located in Porto, Portugal, which already had these pedagogical and curricular assumptions in mind when, in 2015, the study plans of the 1st cycle in Management were reformulated. Some of these changes included the inclusion of an internship curricular unit, necessarily in a workplace context, in the 3rd year, of the 2nd semester; an Entrepreneurship course unit in the 3rd year, 1st semester; and also, two courses in the information and technology systems area: the Information and Knowledge Society course, in the 1st year, 1st semester and the Information Systems for Management course in the 3rd year, 1st semester.

For the purpose of this study, the pedagogical methods (traditional and active learning strategies) used by the teacher of the curricular unit of "Management Information Systems", in the academic year of 2018/2019, will be analysed and discussed according to students' perceptions.

2 Context of the study

The context of the study takes place in the "Information Systems for Management" curricular unit (CU), which is part of the 3rd year study plan of the Management degree programme at Portucalense University, Porto, Portugal. This CU has more than one hundred students enrolled annually, divided into 6 classes of about 24 students each. It has a weight of 5 ECTS and requires 45 contact hours.

Due to some lack of interest in a large percentage of students (around 60%), which was revealed either in the absenteeism from classes or in poor final evaluation results, it was decided, at the end of the 2017-2018 academic school year, that this course should be adjusted. Bearing in mind that the students who attended this curricular unit belonged to a different generation previous cohort (generation Z), the teaching and learning methods and the assessment instruments, as well as the behavioural skills that were intended to be developed by students, were reviewed. Starting from the contribution of this course to the professional profile of students and the nature and objectives of this course in the study plan, the socio-behavioural skills to be developed were readjusted. Skills such as leadership and the capacity for self-criticism and self-assessment started to be developed, instead of skills related to the concern with quality and the ability to organize, plan and manage. Other skills, namely critical and evaluation skills, ability to apply theoretical knowledge in practice, communication and teamwork continue to be developed and evaluated. And, considering the characteristics of the students, a set of active methods was used in the teaching-learning process that had not been used before. These teaching and learning methods used in the development of different skills, both technical and behavioural, are summarized in table 1. In all classes, different class closing activities were used to solidify concepts and the mental map of the concepts explored in the course was gradually constructed.

Table 1. Teaching and learning methods for each skill to be developed

Skills	Methods/ resources	Flipped Classroom	Team Based learning	Brainstorming	Lecture	Demonstration	Gallery walk	Video analysis	Case study and article analysis
Technical Skills	Describing the concept of information system			X					
	Identifying the role of the information and technology systems (ITS)		X				X		
	Knowing the impact of ITS		X	X			X	X	
	Knowing and characterising types of ITS	X	X	X	X			X	X
	Identifying best practices to increase ITS impact	X			X				X
	Using ERP (Primavera), Excel and BI (Qlickview)					X			
Socio-behavioural Skills	Analysis and synthesis	X					X	X	X
	Capacity for criticism and evaluation	X	X	X					
	Leadership		X						
	Ability to apply theoretical knowledge in practice					X	X	X	X
	Capacity for self-criticism and self-evaluation		X						
	Written and oral communication	X		X			X		
	Teamwork		X	X					X

The assessment was continuous and included 5 elements, as shown in Table 2: 1) an interdisciplinary work, with the Strategic Management unit; 2) a written test; 3) participation during classes; 4) an individual practical test, using Excel; and 5) a group test, with Enterprise Resource Planning (ERP) and Business Intelligence (BI) types of software. The assessment through interdisciplinary work included a weighting resulting from peer review.

Table 2. Elements included in Student Assessment

Skills		Interdisciplinary teamwork	Written test	Class participation	Individual practical test (Excel)	Group practical test (ERP and BI)
Technical Skills	Describing the concept of information system		X	X		
	Identifying the role of information and technology systems (ITS)	X		X		
	Knowing the impact of ITS	X	X	X		
	Knowing and characterising types of ITS	X	X	X		
	Identifying best practices to increase ITS impact		X	X		
	Using ERP (Primavera), Excel and BI (Qlickview)				X	X
Socio-behavioural Skills	Analysis and synthesis	X	X	X		
	Leadership	X				
	Ability to apply theoretical knowledge in practice	X	X	X	X	X
	Capacity for self-criticism and self-evaluation	X				
	Written and oral communication	X	X			

3 Methodology

The aim of this study is to analyse students' perceptions about the impact of the use of pedagogical methods (traditional and active learning strategies) inside and outside the classroom. The study sample consisted of 94 students enrolled in this curricular unit of "Management Information Systems".

For data collection, the study followed a quantitative methodology, based on the application of a questionnaire to students enrolled in the course. This approach is justified by the need to collect the opinions of the students i.e. the study was descriptive in nature and statistical techniques were used for the collection and analysis of data. The questionnaire was organized in four main sections, including a total of 26 questions that addressed the following topics: teacher performance (Dimension I), teaching and assessment methods (Dimension II), skills development (Dimension III) and overall satisfaction with the curricular unit (Dimension IV). All the questions were close-ended type and used a a five-point Likert scale ranging from: 1-Not at all, 2- Very Little, 3-More or less, 4- A lot and 5-Very Much. Data collected were analysed and treated by using IBM SPSS Statistics 26.0.

4 Analysis and discussion of results

This section presents and discusses the most relevant results obtained according to each of the four dimensions of the questionnaire: teacher performance (Dimension I), teaching and assessment methods (Dimension II), skills development and overall satisfaction with the curricular unit (Dimension III / IV).

4.1 Teacher performance

In order to assess the teaching performance of the teacher, the following criteria were included in the questionnaire: commitment, motivation, scientific preparation, clarity in explaining the contents, interaction with students and clarity in clarifying doubts. The results obtained in this dimension were all classified above level 4, which shows a very positive opinion of students about the teacher's performance. This very positive opinion of students could also be understood as a result of their own observation and experience in the classroom, this is, applying new teaching methods by the teacher led to the development of new cognitive and socio-behavioral skills, in addition to the digital skills (information technologies) so necessary in their future professional life.

4.2 Teaching and assessment methods

In this dimension, students evaluated their degree of satisfaction with the 10 conventional and unconventional teaching methods used (see table 1). One issue that should be highlighted is the high number of missing values in relation to the evaluation of teaching methods that involve the direct and more active participation of students (such as Flipped classroom, Walk Gallery, etc ...). For all methods, we found that at least half of the students assign a rating of 4 or more on the scale used, that is, most of them appreciated the use of all these methods a lot or very much. It is also interesting to mention that, for students, the method that was least evaluated by them was the use of the expository method / Slides (conventional teaching method). Regarding the average of the assessment of the methods (Figure 1) and their dispersion, we conclude that the mean degrees are all above 3.5 (which is quite high) with reduced dispersion (coefficients of variation less than 30%). In particular, it is interesting to note that the methods that receive the lowest rating are those with the highest dispersion (such as Flipped classroom, Gallery Walk, Case study and paper analysis in classroom and Slides). That is, the students' opinion is less consistent for those methods.

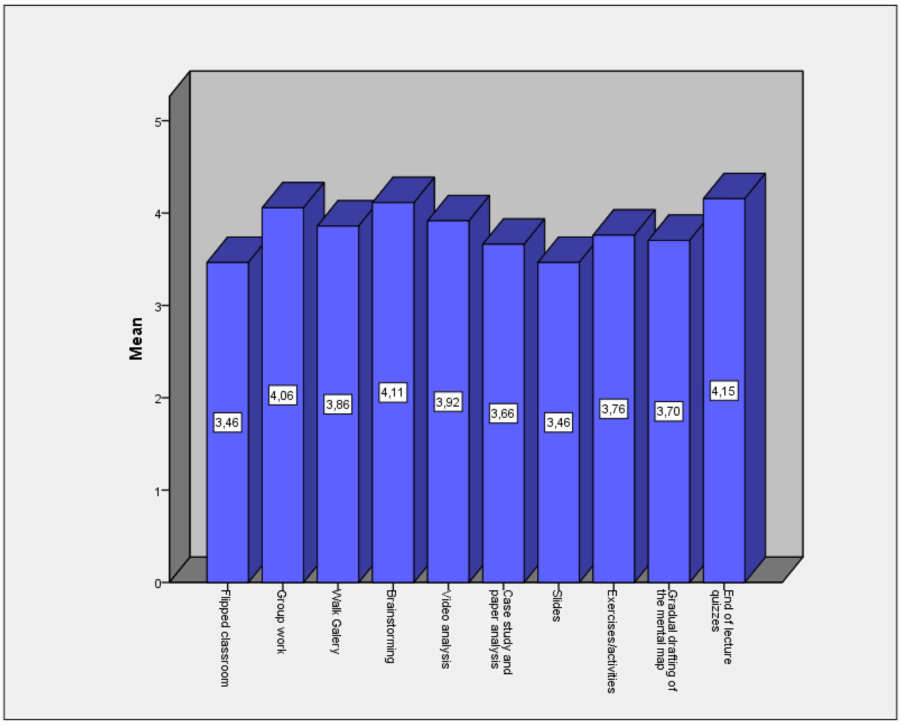

Figure 1. Evaluation of teaching methods by students (mean).

In order to check if there are any differences in student evaluations regarding the application of less conventional methodologies, we built boxplot clusters (Figure 2). We can conclude immediately that, the teaching methods "Brainstorming" and "Quizzes" have identical evaluations by students and it is for them that the students' evaluation is most positive. For the "Case study and paper analysis" and "Mental map" methodologies, it is also found that the students' opinion is identical. In contrast, "Flipped classroom" is the unconventional method with less favourable opinion (perhaps due to being the only one that is applied outside the classroom). In this analysis, it is also worth mentioning that the "Gallery Walk" is the method that presents greater variability, that is, greater dispersion in the evaluations. However, this is the only unconventional method that has no outliers. It should be noted that all the others have moderate outliers (unfavourable opinion´s).

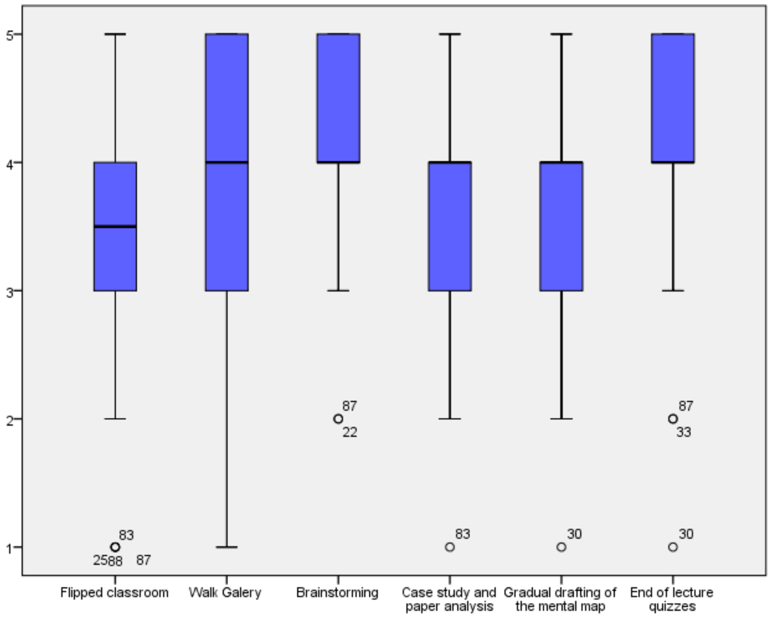

Figure 2. Boxplot clusters for unconventional methods.

In this study, the methodologies used were also evaluated as a whole, concluding that they made the classes much more interesting and allowed the student to behave more actively in the classroom (means above 4). Furthermore, evaluating the benefits of the methodologies used (more interesting lectures and more active engagement) in adapting to the objectives of the CU, we found that there is a moderate positive association which is significant at the level of 1%, that is, for example, the more the students find that the methods make the lessons more interesting the more they consider that they are suitable to the objectives of the course (Table 3).

Table 3. Spearman's correlation coefficient between the adequacy of teaching methods and the benefits of methodologies.

Correlations

			The teaching methods were appropriate to the aims of the course	The adopted methodologies made the lectures more interesting	The adopted methodologies allowed a more active engagement by students
Spearman's rho	The teaching methods were appropriate to the aims of the course	Correlation Coefficient	1,000	,592**	,468**
		Sig. (2-tailed)	.	,000	,000
		N	93	93	93

**. Correlation is significant at the 0.01 level (2-tailed).

4.3 Skills development / Overall satisfaction with the curricular unit

Regarding students' evaluation about the skills developed in the CU, we found that the more students consider that the CU was important in the development of their skills, the better they relate the acquired knowledge with the application to future professional life(r_s=0,52).

Finally, to evaluate the impact of the application of these teaching methods, the students' opinions were analysed regarding some parameters of interest (namely the balance between theory / practice and the resources made available) that interfere in the global evaluation of the CU. According to the results obtained, we can conclude that at least half of the students gave a very positive overall assessment. Furthermore, it was found that the greater the balance between theory / practice, the more positive the student's evaluation of the CU and, more adequate are the resources available for the application of the methods, the more positive the student's evaluation is (Table 4).

Table 4- Spearman's correlation coefficient between the parameters that affect the CU evaluation

Correlations

			The course met the expectations	The balance between theory and practice was appropriate	The resources made available were appropriate
Spearman's rho	The course met the expectations	Correlation Coefficient	1,000	**,606****	**,483****
		Sig. (2-tailed)	-------	,000	,000
	The balance between theory and practice was appropriate	Correlation Coefficient	-------	1,000	**,507****
		Sig. (2-tailed)	-------	-------	,000
	The resources made available were appropriate	Correlation Coefficient	-------	-------	1,000
		Sig. (2-tailed)	-------	-------	-------

**. Correlation is significant at the 0.01 level (2-tailed).

As expected, we also found that the more positive the students' opinion was about the CU, the more they think it is important in the development of their skills (r_s = 0.53), as well as, the more they consider that the knowledge acquired in the CU may have more application in your future professional life (r_s = 0.50).
As a curiosity, students when asked about the availability of slides in Moodle after class, most of them revealed not to be in agreement or to be slightly in agreement.

5 Conclusions and Final Remarks

This paper aimed to analyse and discuss students' perceptions about the of the use of traditional methods and active learning strategies in the classroom. In general, it is possible to conclude that at least half of the students who participated in this study revealed a positive perception (classification above 4, in a Likert scale) in regard to the active learning strategies implemented in the classroom by the teacher. Students also showed a very positive opinion about the teacher's performance. Students considered the classes to be more interesting and engaging with the use of these active learning strategies, as opposed to the more traditional lectures, for example, when using presentations with slides.

Another interesting conclusion is that the more students consider the teaching methods make the classes more interesting, the more they believe that the methods are adequate to develop the course's learning outcomes. It was also noticed that the more positive students' opinion is about the curricular unit, the more they believe that the curricular unit is important for the development of their cognitive knowledge in the field and also the social and interpersonal competences required for their professional practice. This is also related to a greater awareness, by students, of the importance of the learning outcomes developed in the curricular unit which will have more application in their future professional practice.

In sum, this study provides evidence of the positive impact, perceived by students, of the curricular and pedagogical changes in teaching and assessment methods used in the classroom, which is aligned with the purposes and demands of the development of the education skills for the 21st century (World Economic Forum, 2016).

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Characterization of the Operators Training Process in an Industrial Company

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Abstract

Training operators in industrial contexts is a demand that most of the industrial organizations must deal with, and engineers are the trainers in many cases. Thus, engineers may be required to deal with the development of a training environment and a competences assessment system in training settings. This paper aims to characterize strategies for planning and implementation of an operator-training process for a specific production process, namely automatic insertion lines of electronic components, in an automotive company. The developed work included the following three steps: (1) documental analysis, (2) observation of the current training process, and (3) interactions between the researchers involved in the case study and the company's collaborators. During this characterization, it was possible to identify some strategic learning approaches, and three main phases of training: the Initial Training which consists in an general explanation of the content in an integration phase; Theoretical-Practical Training which consists in a specific phase of mandatory content for operations development; and the Validation of Aptitude / Knowledge which consists in complementary content that is focused to ensure the competences development through an assessment of the trainee operator. This case study may give support to practitioners and researchers dedicated to this theme.

Keywords: Industrial training; Training phases; Engineering Education.

1 Introduction

Over the years, the world has been transformed by the industry and nowadays manufacturers are facing an increasing demand for new products and technologies. This dynamic demand requires qualified people. When the subject is production processes, it is possible to imagine a system operating in a plant with operators running complex machines (Ayarkwa et al., 2012; De Vin et al., 2017). In order to ensure a system of machines and then a good development and delivery of products to customers and market with expertise, an industrial operation is needed (Erol et al., 2016). Naturally, for this kind of operation to be successful, well-developed people are required and this development happens through the design and implementation of a training process which enables operators to do their jobs effectively (Agnaia, 1997; Rus et al., 2015).

Mavrikios et al. (2013) claim that to respond to operation role, manufacturing training should follow new approaches to prepare industry for innovative processes and for projects that seek to maintain market competitiveness (De Vin et al., 2017; Korn & Schmidt, 2015). The characteristics of manufacturing training present challenges and goals for the operators using strategies that promote synergy between the training and the industry needs. The comprehension of the requirements of the industry training and the definition of subjects and contents, could follow a pedagogical instructive approach or the training could been structured following the current company and daily work reality (Ayarkwa et al., 2012). The adaptation of the educational content and its delivery mechanisms to the new requirements of a knowledge-based manufacturing, the provision of integrated engineering competences, including a variety of soft skills, and the promotion of the innovation, are considered as major priorities of industrial training. Create an innovative training process, in the workplace, that exploits the potential of existing technology, is crucial when the focus is on developing technical and transversal skills (Ayarkwa et al., 2012; Mavrikios et al., 2013).

Bansal et al. (2010) explains that although curricula in training centres and universities have provision for industry, for example, and many training schemes are in place, especially for professional courses, some programmes have not made the impact expected and need quick changes involving the practical environment.

In order for learners to meet the skills requirements of an ever-changing labour market, adequate resources need to be invested in appropriate forms of work experience and in building up transferable skills (Ayarkwa et al., 2012). The same authors argue that learners can acquire new skills during a training process, and that training provided by organisations aims to offer learners the necessary work exposure, so they are able to adapt to the work environment during the learning journey.

Ayarkwa et al. (2012) also explain that the work environment provides an on-the-job training with a real-life job experience, making the trainee operator more aware of the needs and expectations of industry as well as making them more "ready collaborators". For the learning environment to be implemented in this training process, two fundamental characteristics are defined: personalization and adaptability (Xie et al., 2019). The personalization of the learning environment corresponds to the presentation of an environment according to the preferences and characteristics of the users. Adaptability represents the configuration according to the performance and needs of the participants as they interact with a real context.

Agnaia (1997) claim that a training development in industrial context must be addressed and deployed as any other management and process activities, arguing that it must be influenced by the other activities of the company, systems, and institutions in its environment. It is also important, for those who are trying to make the training process development supported by management, to understand their organizational environment in order to meet strategy with customer needs. Musgrove et al. (2014) highlighted an important point in the training process, related to different parts of the company as a human resource (HR). They contend that when it comes industrial training development, the HR has a role as interventionist, providing support, with a process eye and creating a sustainable talent pool through helping in the building of the necessary skills for companies success, aligned with managers to structure the adequate training (Agnaia, 1997; Dubey & Gunasekaran, 2015; Musgrove et al., 2014).

Dubey and Gunasekaran (2015) defend that training must focus equally on hard and soft skills; that is why, for them, building a sustainable industrial skill is a requirement as operators face challenges daily and problem solving must be a natural practice. The authors also contend that industry managers must hold knowledge to appreciate environmental, social, and economic dimensions. Furthermore, management must possess the desired soft skills, which include leadership, effective communication, and teamwork skills. That is why their operators skills will reflect them, at work and in strategy (Dubey & Gunasekaran, 2015; Rus et al., 2015).

Rus et al. (2015) explain that in a training process, to ensure quality and confidence, a mentor and a mentee model are very important aspects. They recommended that a right mentor must be identified for a group of mentees. It can be translated as an experienced operator able to help the industrial learners as soon as their needs come. Dubey and Gunasekaran (2015) indicate that the training "must include inbound and outbound modules". The inbound module should include theoretical inputs covering fundamentals of industrial process and evolution of the production procedures. The outbound training is a quite proven methodology to improve learners' leadership skills, empowerment, problem solving capabilities, as well as team work and effective communication skills (Dubey & Gunasekaran, 2015).

Dubey and Gunasekaran (2015) point out that the field of vocational training emphasizes individual skills through experiential learning, that is in practical context. They said that empirical learning or learning by doing something to get experience is rooted on the notion that learners have not the perception of the fundamentals that remain otherwise unchanged but is instead established and improved by experience (Dubey & Gunasekaran, 2015; Rus et al., 2015). The basis for evolving all these competences is drawn from the notion of apprenticeship, which includes a diversity of fields. Ryberg and Christiansen (2008) contend that currently, learners imitate the behaviour occurred where they received the training. Training for training will give confidence to the trainees, allowing them to enter the next stage. The final stage is where the trainees can already teach the skills they have learnt to others (Rus et al., 2015).

According to El-Bishouty et al. (2019), the skills that must be developed attend simultaneously as a guide for planning teaching-learning activities and as parameters for the construction of assessment questions and for the identification of performance. It is up to the trainer to formulate questions and label them so that the training environment can apply them to the learners to promote a progressive learning of such competences.

When learners undertake training on this process, they are subjected to an assessment. If they do not demonstrate familiarity with the process, obtained through previous experiences and learning experiences in the context of training, or are unable to answer most questions, they are guided to repeat the training. Learning tasks must be responsive to experiences and process, allow for changes and adapt to behaviour (El-Bishouty et al., 2019). The way a person understands concepts and interacts in the training environment allows him to recognize his behaviour (Azzi et al., 2020; El Guabassi et al., 2018; El-Bishouty et al., 2019; George & Lal, 2019; Jafari & Abdollahzade, 2019). This recognition can be carried out based on aspects related to the learning process, which includes cognitive, emotional, and psychological characteristics. It is important because it can contribute to improve performance, stimulate motivation, and decrease learning time, that is, to transform learning into a more positive and more effective experience.

This paper focuses on the characterization of a training process in an automotive manufacturing company, introducing what is currently performed in a real manufacturing context. It is also related to the development and delivery of a learning and training process, besides the knowledge and competences evolution of the operators and the needs related to work.

2 Training Process Characterization

The content exposed in this section presents how the training process is developed and evolves over time, as well as the competences acquired by the operator. It is possible to observe the complexity regarding the work developed and the industrial plant needs. The operation involves different steps that depends on each other and must be very well executed to ensure the quality of the final product.

2.1 Training Strategy

The complete training program that is performed, includes: (1) general content explanation in the initial training, aimed at integrating trainee operator to updated technical management guidelines (which are sensitive to organizational policies); (2) mandatory content, that is a theoretical-practical training (whose application is immediate during the execution of operations on the production line) and, finally; (3) complementary content as validation of aptitude / knowledge that consolidates the competences for autonomy of the trainee operator who is assessed to identify the intermediate or advanced level (in terms of experience and mastery of fundamentals).

This training can be an essential technique for carrying out not only workplace but also complementary activities. In that point it possible to see the alignment with the arguments of Ayarkwa et al. (2012) and Dubey & Gunasekaran (2015) presented in the introduction which explain that an effective industrial process must to be developed in a practical environment.

The essential technical training modules, i.e., the mandatory modules that enable trainee operator to perform the operations expected in the automatic insertion line, are:

1. Critical Standards - SMD (*Surface Mount Device*),
2. Laser Process,
3. SPP (*Solder Paste Printing*),
4. Glue Process,
5. SPI (*Solder Paste Inspection*),
6. Insertion Process,
7. Material Splicing,
8. MSL (Moisture Sensitive Level),
9. Reflow Soldering,
10. AOI (*Automatic Optical Inspection*) SMD.
11. 14 Quality Principles – Annual,
12. AOI SMD – Every two years,
13. X Ray - Every two years,
14. Soldering rework - Annual,

15. Selective AOI – Every two years,
16. SPI – Every two years.

Besides being given to new workers, the complementary training modules can also be attended, in some cases, by more experienced production operators. The purpose is to expand their knowledge and provide them with the opportunity to practice new experiences (with a view to achieving autonomy). The complementary training modules are:

1. Production start checklist - SMD,
2. Basic Concepts - SMD,
3. KPI (Key Performance Indicators),
4. QCO (Quick-Change Over),
5. 5S circuit,
6. Assemble and disassemble of feeders,
7. Exchanged material,
8. Autonomous biweekly maintenance,
9. Panasonic feeders autonomous maintenance,
10. NIM (Norm Internal MOE), Procedures and Standards - SMD,
11. TOP defects,
12. Minor problems resolution.

In addition to training new operators, there is an annual training plan that contains a set of mandatory update modules (refresh). Due to the analysis of the indicators related to "Main internal and customer defects", "new processes", and "process deviations", proposals for other modules are developed. When trainee operators participate in training activities, they have already had experiences in the production lines observing some experienced operators (called versatile operators) and, therefore, the training sessions aim to systematize the knowledge they already have. This provides the conceptual foundations for developing analytical skills, elimination of doubts or gaps in perception and train decision-making by presenting challenging scenarios with known occurrences, some already experienced by the participants, others not yet.

This part of the training process matches with the indications provided by Dubey and Gunasekaran (2015) and Rus et al. (2015) in the Introduction of this paper, when they explain that learners must receive training to develop soft skills in order to have a critical sense of decision and problem solving as well. The trainer conducts a survey on the previous experience of each participant, guided by the answers to ensure the effectiveness of the instructions. The trainer also ensures that the fundamental theoretical content has been fully memorized and assimilated and reads body communication and behaviour to identify signs of dispersion or fatigue.

2.2 Training Phases and Assessment

To fulfil the training process with excellence, some phases must be followed to ensure step by step apprenticeship. The process is illustrated in Figure 1 and consists of the following phases:

- Phase 1: Initial training for the integration of trainee operators.
- Phase 2: Theoretical-practical training in the workplace and in the training room:
    - During a first observation period, the trainee operator observes the versatile operator (experienced operator) at the workstation.
    - In a second supervised period, the trainee operator performs tasks at the workplace under the supervision of the versatile operator.
    - Technical training with theoretical-practical modules in parallel with the practical activities and according to the levels of aptitude observed by the supervisor.
    - Complementary training with theoretical and practical modules in parallel with practical activities.
- Phase 3: Validation of aptitude / knowledge:
    - Suitability validation based on a knowledge assessment form.

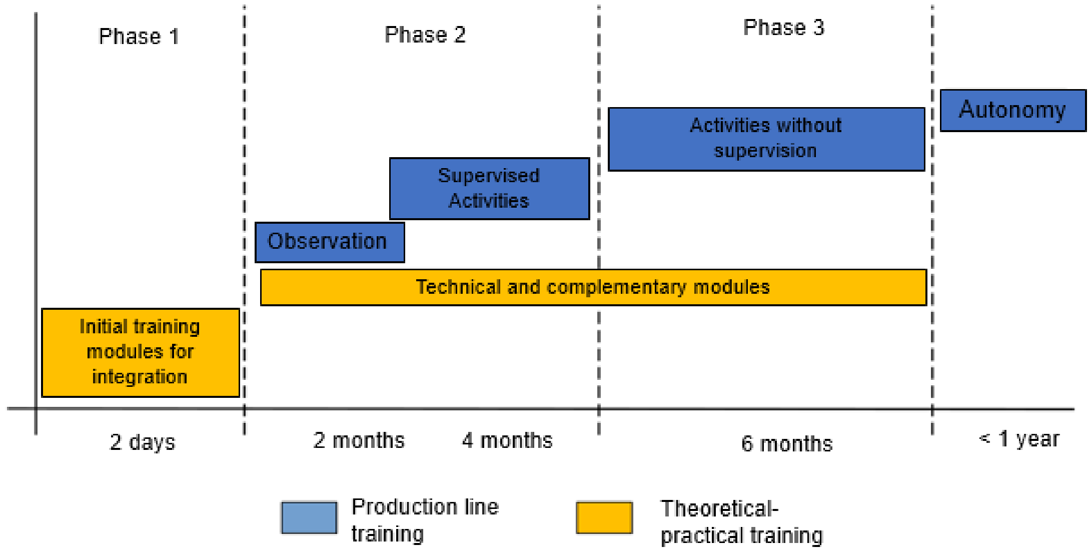

Figure 1. Phases of the training process.

The first phase lasts for two days and takes place in the classroom. The second phase consists of an initial stage of observation of the action of the versatile operator in production line, lasting two months, approximately. After the observation period, the trainee operator can carry out activities under the supervision of the versatile operator. In parallel with these sub-phases of observation and work under supervision, operators in training attend technical modules that are relevant to their experience on the production line. These technical modules are taught in a theoretical-practical format in the classroom.

Next, the contents and planning of the theoretical and theoretical-practical modules included in each phase are presented.

2.2.1 Phase 1 – Initial training for integration

This training is provided by process specialists, team / shift leaders and Quality Engineers, being a mandatory training phase that lasts two days in the classroom and the modules are distributed according to Table 1.

Table 1. Initial training for integration.

Day 1	Day 2
General presentation and considerations-SMD	Checklist start-SMD
Production process flow	Critical Standards-SMD
Basic Concepts-SMD	Ordering materials: PDA and SIIA
	Exchanged material
NIM, Procedures and Standards-SMD Process confirmation	SMD components
	Close of training

2.2.2 Phase 2 - Theoretical-practical training

In the second training phase, up to approximately 6 months, trainee operators, still in the condition of observers, must carry out the technical training modules essential for the performance of functions at the workstations and complement according to the definitions of the factory and the section. The theoretical-practical modules are divided into two parts, depending on the evolution of the skills of the trainee operator. The modules of part 1 are shown in Table 2.

Table 2. Technical and complementary training – part 1.

Day 1	Day 2	Day 3
Material splicing	Glue Process (Ipag and Asymtek)	Autonomous biweekly maintenance
Laser (after 2 weeks)	5S circuit	Panasonic feeders autonomous maintenance
Assemble and dismantle feeders	TPM (QCO, OEE, KPI)	

The part 2 modules are shown below in Table 3.

Table 3. Technical and complementary training – part 2.

Day 1	Day 2	Day 3	Day 4	Day 5
Solder Paste Printing	SPI	MSL	AOI SMD	TOP of defects-SMD (internal and customers)
	Validation of SPI images	SMC		
	Insertion Process	Reflow Soldering	Images validation	Resolution of minor problems

2.2.3 Phase 3 - Validation of aptitude / knowledge

Phase 3 begins when the trainee operator performs the activities without the need for supervision and ends after the validation of the aptitude form. After this training period of phase 1 and phase 2, the operator in training is assessed by taking the aptitude exam and is also asked to complete an assessment form of the training process itself. Once approved, the cuff that identifies the training condition is removed, thus allowing the trainee operator to carry out the activities without supervision. At this stage, trainee operators still participate in relevant technical training modules considering their level of experience.

The trainee operator is considered fully autonomous after approximately one year of experience. It was possible to observe in this practice of the industrial real context, what was explained by Agnaia (1997), and described in the introduction section, about the importance of activities supervision and then the need of let the learner do the tasks with autonomy.

However, in this third phase, which takes place in a period of up to 6 months approximately, content review activities identified in the aptitude exam may be envisaged.

3 Discussion

Regarding the efficiency of the current training process, the integrating and training strategy of the trainee operators in the automatic insertion lines is proving to be effective looking for the current process. It is based on the direct observation of versatile operators, team leaders and support personnel, namely technicians, process specialists and Quality Engineers. However, the process, from the entry of trainee operators until they reach full autonomy, is time consuming, with an average duration of 1 year, but once one sees this as a process that can be improved, it is possible to find the path to reduce the time required to reach autonomy.

This process involves many human resources and equipment, and it is necessary to invest a lot of time in training, support, monitoring and clarifying questions. Thus, it is understood that the efficiency of the current training process can be improved by at least two point of view:

- Compressing the total duration of the training process.
- Using digital learning simulation systems, aiming to use fewer resources.

The first one will benefit from a business process perspective applied to the training process. As it is well known in industry, a continuous improvement perspective applied to processes will allow reducing throughput time and utilization of resources. Thus, the authors' first proposal would be to create a new model of the training process(es) and make direct links between the identification of required competences from the production system itself to the way the training will be designed, implemented, assessed, and evaluated. In summary, the first recommendation would be to develop a process view of the training process applying the best-known solutions for effective learning. As an example, there would be a good opportunity to implement instructional design (Arghode et al., 2018; Branch, 2009; Edmonds et al., 1994) concepts and active learning (Freeman et al., 2014) methodologies as higher learning effective solutions.

A digital learning simulation system, aiming to use fewer resources, could be focused on Augmented Reality (AR) and Virtual Reality (VR). Such a VR/AR environment should not be just an interaction environment; the principles of Game-Based Learning (GBL) must be considered and corresponds to the modelling of each participant as a player. The player acquires knowledge as it interacts with content and activities presented in the style of a game or in a storytelling structure, in which participants are confronted with challenging situations and need to solve problems to move forward. Game Design elements can include collaboration, roles, objectives, challenges, exploration, storytelling, complexity, competition, strategy, communication, feedback, augmented reality, control, interactivity, realism, rules, frameworks, curiosity, expression, involvement and rewards (Jafari & Abdollahzade, 2019; Paravizo et al., 2018).

As could be observed from the content exposed in the introduction section, until the understanding of the real context, the industrial training process is not a set of operations that are linearly interconnected. The employees already bring with them some experience in the production line, despite being very limited and strictly mechanical (repetition). Thus, training does not aim to train the performance of the sequences of activities, but rather to systematize previous knowledge with concepts, connections and relationships that give meaning and offer a sense of work organization. Thus, the role of the trainee operator is very important because his/her job consists, practically all the time, of probing weaknesses in perception, gaps in systematized knowledge and tests, in relation to the decisions necessary to face the events that are predicted in production line.

4 Conclusions

An important aspect observed is the conduct way that the company, and the engineers assuming the trainer role, exercise during the training to choose the best strategy to maintain the attention of those present and ensure that the knowledge has been properly assimilated. That part of the study confirms what was explained based on the authors cited in the introduction section, which means a strategy designed to provide the best way for the trainee operator acquire knowledge and develop competences. In addition, the process of follow-up to ensure efficacy and the engagement of tasks may help the operator to develop soft skills. This type of development is a kind of bonus to the trainee operator and permits to fulfil gaps solving problems that appear in daily work at the company. The assessment is performed to understand if the operators acquired the knowledge in depth to develop their work, but could also assess soft skills if that is a company goal as well.

The learning environment must be open, meaning both the training path, as well as the interaction with the factory environment in the daily work as needed. Therefore, the training model for industrial operators must have sufficient resources to guarantee learning and skills development. However, the natural evolution of the production processes require the development of new operators, and this requires the involvement of process engineers and specialists in the design and deployment of the training process.

An important conclusion of this work is that the training processes in an industrial environment must be considered in the same way as the other processes in the company (e.g., production processes) that are constantly analysed in order to be improved (continuous improvement). This is the only way to develop training systems that are not static, but that can evolve according to the changes that occur in the surrounding context. Thus, it becomes evident that the reduction of the time needed for trainees to develop the necessary skills to achieve the desired autonomy is only possible if the training processes are also subject to continuous improvement efforts.

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Industrial Training Qualitative Evaluation with Fuzzy Logic and an Experience Classification Method

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Abstract

It is usual that companies must develop their own training processes, adaptable to their own production systems. In fact, the evaluation of the training process is a function of significant importance and must guarantee means for the identification of demands for corrective actions and for a procedure that ensures the continuous evolution of the process, therefore, that meets a dynamic of continuous improvement. The evaluation of a training process aims to provide information to support the decision making of the trainer, the process manager and other decision makers. This paper aims to propose a model of qualitative evaluation for industrial training based in fuzzy logic and a method of classification of training experiences. This training evaluation model considers the level of uncertainty that exists in qualitative responses (from trainees) and based on this, proposes a method for defining priorities for decision-making and carrying out improvement actions with the aim of evolving the training program. This action research was developed through a theoretical framework guided by the characterization of the context and the opportunity for improvement identified in this characterization, development of the model, and finally in the application of the model in an industrial training process.

Keywords: Industrial training; Training evaluation; Fuzzy logic.

1 Introduction

According to Loch et al. (2018), training in the workplace has received attention from researchers and practitioners in industry because it has been directed at meeting the implications of the increased complexity of industrial machinery. Training processes are aimed at developing competencies to perform tasks or carry out procedures proper to the work act. Ilyas & Semiawan (2012) advocate collaborative action between industry and education to develop means and implement effective means for effective excellence in manufacturing.

For Hecklau et al. (2016) the performance and competitiveness of an organization depend heavily on human resource management and one of the most important elements of this functional area is human resource development. According to the authors, human resource management can be defined as a strategic approach to the development and employment of a qualified workforce that is highly committed to the company's objectives. This vision inevitably goes through the action of professional education, learning and training of people individually or in teams, in aspects that are sensitive to the organizational strategy and therefore to the performance of any organization in terms of competitiveness and operational goals.

There are several models for developing and implementing training processes in the industry. Among them one can cite as main ones: Production-Based Education – PBE (Ilyas & Semiawan, 2012), Work Based Learning – WBL (Garnett et al., 2016; Helyer, 2015), Learning Factories (Abele et al., 2017), Lean Production Training (De Vin et al., 2017). Many other proposals originated from successful private experiences are disseminated in the literature. All these models consider the evaluation of the training processes.

Carlucci et al. (2019) argue that evaluation, especially in the field of education, has two distinct dimensions: (i) identification of problems or opportunities for improvement (that require corrective actions), and (ii) evaluation at a higher level of abstraction, aiming at strategic planning for the realization of higher order actions, i.e., that results in the evaluation of the model.

An important element of the evaluation of the training process is the subjective assessment of both trainees and trainers. Therefore, Carlucci et al. (2019) proposes a framework to adequately analyse the quality of the teaching process in the light of the imprecision and uncertainties present in subjective assessments. Once the various courses planned in the training process have been completed, the participating agents must answer a questionnaire on their perceived quality, which can be observed as the participants' judgment of their experience in the process, either as trainees or as trainers.

The instrument integrates two methods, the u-control chart and the ABC analysis using fuzzy weights. By means of the control charts, trainees' assessments are analysed to detect courses that are outside the control limits, and ABC analysis using fuzzy weights deals with the imprecision and uncertainty of those assessments in order to provide a risk map of potential areas for improvement. In general, the authors present a management tool capable of indicating the need for short-term corrective measures, by means of the control charts, and pointing out areas that have potential for improvement in the long term.

Unlike propositional logic and predicate logic, also known as Boolean logic, in which equations are composed of arguments with unambiguous quantification, fuzzy logic, as stated by Williams (2009), proposes inferences that are closer to the human way of thinking. For example, in propositional logic, to analyse the height of a person, one considers the results "high" and "low" and establishes objective values as criteria for choice to fit the situations in such classifications. Fuzzy logic is able to accommodate nuances of perception about these qualities and admits gradations between them in order to predict other qualities such as "very low", "low-medium", "medium-low", "medium", "medium-high", "high-medium" and "very high". Therefore, there are no truths, but degrees of truths, or different degrees of association. In Boolean logic the results are 0 and 1, while in fuzzy logic, in addition to the absolute values 0 and 1, any value in between is possible.

Nakashima et al. (2004) clarify that the application of rules based on fuzzy systems for the control of problems is common, and more recently the application of these same rules for the classification of patterns has emerged. The authors state that weight is a mathematical tool to enable this application. A weight is assigned to each given pattern based on the class distribution of its neighbouring patterns so the number of neighbouring patterns of the same class determines its values proportionally. In fuzzy rules, patterns with small weights are not considered in the classification.

It is argued in this article that one should consider training as an organizational process, since if the objective is the organization's performance, it must be conceived for the organizational architecture and based on it, in a way that it is organically integrated with management actions and linked to the decision-making process.

Therefore, in a complementary way to the good practices already established in traditional models, the training process is also considered as a set of integrated activities that aim to meet a goal in the first instance that is aligned with the objectives of the various organizational instances. The tool that allows planning and managing this kind of perspective is the so-called Instructional Design that can be operationalized by the ADDIE concept – Analyze, Design, Development, Implement and Evaluate (Branch, 2009; Edmonds et al., 1994; Gibbons & Yanchar, 2010; Hokanson et al., 2008; Reiser, 2001).

Based on the ADDIE concept, the evaluation activity in the training process is thought and executed in an integrated and aligned way with the other activities. In this article, it is intended to present a model of qualitative evaluation for industrial training based in fuzzy logic and a method of classification of training experiences with ABC analysis as a strategy to promote improvements responsible for the evolution of the model and the training process.

2 Methodology

This article is the result of the observation research procedure followed by critical analysis supported by a literature review for the purpose of theoretical background and study of precedents. Guided by the experience gained during the immersion process of the authors in the application environment and by previous experiences, a search for references was conducted. The research process went through two stages, namely: (i) the immersion stage in the environment where the improvement actions were intended, and (ii) the solution building stage, based on the knowledge and previous experiences of the researchers and practitioners, besides the execution of the improvement actions in a collaborative way with the professionals. The construction of the solution, including research on similar precedents, was guided by the need to make the notion of expected quality of the training process, observable and tangible. This provides a way to develop an evaluation instrument that would take into account the subjectivity of the participants as to their level of satisfaction with the training experiences so that managers would have an effective resource for decision-making. The solution reached is based on fuzzy logic and experience classification methods.

3 Expected quality of training

In the previous training process, the evaluation of the training by the trainees was carried out as illustrated in Table 1.

Table 1. Evaluation of training by trainees (previous process)

Please evaluate the courses using the followed scale: 1 – It needs of revision; 2 – It coult be improved; 3 – It does not need of revision.

	Day	Courses	Evaluation		
			Content	Trainer	Total
Week 1	1	Presentation	2	3	2
	2	Basic Module	3	3	3
	3	Folder Printing	3	3	3
	4	Ordering materials	2	3	3
	5	Insertion process	2	3	2

The disadvantage of this evaluation is the difficulty in identifying structural change needs of a training, i.e. it requires revision at the level of the dimensions of Instructional Design – Analysis, Design, Development, Implementation and Evaluate. The practical result of the previous evaluation model confirms the aspect pointed out in the literature review. That is, the evaluation expressed the experience of each trainee and served to identify isolated occurrences, of difficult treatment, because it reached the knowledge of the managers only after it had happened and, in general, they were of the type that were not repeated in the same conditions and with the same effects.

4 Results

A new model of subjective evaluation was developed and adopted, which can identify problems of greater complexity. Fuzzy weight is recommended because of the degree of imprecision and uncertainty that subjective evaluations of trainees have. The function membership is illustrated in Figure 1 and shows intersections between responses. Thus, as a base for modelling, a Likert scale from 1 to 4 was defined where the options mean "Definitely yes" (*dy*), "More yes than no" (*my*), "More no than yes" (*mn*) and "Definitely no" (*dn*). The *dy* answers were given weight 1, the *my* answers weight 0.5 and the others weight 0 (see next).

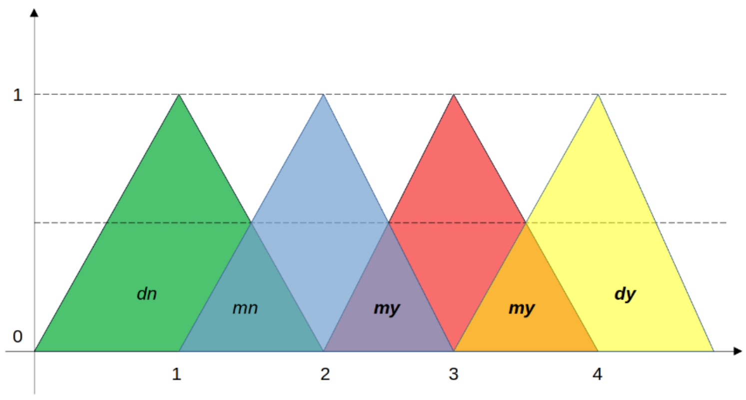

Figure 1. Membership function

It is suggested that responses should also be subjected to an ABC curve analysis, as this is a Pareto analysis used to categorize data according to degrees of importance. Based on the authors Carlucci et al. (2019), the distribution of classes should serve to build a risk map defined as follows: A (low risk) 0-75%; B (medium risk) 75-90%, and; C (high risk) 90-100%.

An example of the new questionnaire developed can be seen in Table 2 and an example of the data analysis process is represented in Table 2.

Table 2. New model of questionnaire

Please evaluate the training listed below. For the question "Does it need revision?", please use the following scale: DY – Definitely yes MY – More yes than no MN – More no than yes DN – Definitely no			
Day	Course	Content	Trainer

The new model considers the entire evaluation history, at least 99.9997% of the evaluations in order to comply with the Six Sigma standard recommendation for process monitoring (Carlucci et al., 2019). The scale has changed, and one should now answer the question: does the training need revision? The answers should be "definitely no" (dn), "more no than yes" (mn), "more yes than no" (my) or "definitely yes" (dy).

The answers dn and mn were discarded in the analysis and the weights 0.5 and 1.0 were applied to answers my and dy, respectively. These weights are applied to balance the scores according to the existing diffusion in subjective questions. The calculation of the ABC curve was parametrized as follows: A – 0-75% (low priority), B – over 75% and under 90% (medium priority) and C – over 90% (high priority). With this, managers have an efficient tool to prioritize the reconfiguration of training.

An important factor in using the ABC curve to prioritize course reconfiguration actions, in response to subjective evaluation, is the slow response time for improvements to begin to affect the curve substantially since it reflects the processing of historical data and it is natural that new positive assessments remain diluted in older negative assessments. This effect is expected and important for the methodology, since the proposal involves a permanent monitoring of the measures that ensure a continuous improvement so that the perspective of prioritization refers not only to corrective actions, but also to the analysis and monitoring of the effectiveness of corrective actions. In other words, a negatively assessed course needs improvement actions, and a period of monitoring the effects of these actions until the improvement becomes consolidated. The evidence of the improvement consolidation is the grade changing from A to B, or from B to C.

Table 3. Evaluation of training courses, distribution of data

Training evaluation																				
Question: Does the training need revision?																				
	Total responses								Fuzzy											
	Content				Trainer				Content				Trainer							
	DN	MN	MY	DY	DN	MN	MY	DY	DN	MN	MY	DY	DN	MN	MY	DY	Points	%	Sum %	Class
Opening of stop latches	40	2	1	1	40	3	1	0	0	0	0,5	1	0	0	0,5	0	2	0,67	0,67	A
Ordering materials	40	2	1	1	40	2	2	0	0	0	0,5	1	0	0	1	0	2,5	0,83	1,50	A
Insertion process	40	2	0	2	40	3	1	0	0	0	0	2	0	0	0,5	0	2,5	0,83	2,33	A
Coil splices	39	2	2	1	39	3	2	0	0	0	1	1	0	0	1	0	3	1,00	3,33	A
Starter Chcklist	25	10	7	2	40	3	1	0	0	0	3,5	2	0	0	0,5	0	6	2,00	5,33	A
Assembly of feeders	25	10	5	4	39	4	1	0	0	0	2,5	4	0	0	0,5	0	7	2,33	7,67	A
Folder Printing	15	16	10	3	39	3	1	1	0	0	5	3	0	0	0,5	1	9,5	3,17	10,83	A
Production process flow	15	16	6	7	38	4	2	0	0	0	3	7	0	0	1	0	11	3,67	14,50	A
QCO SW + HW	20	9	8	7	40	4	0	0	0	0	4	7	0	0	0	0	11	3,67	18,17	A
Glue	16	12	10	6	40	4	0	0	0	0	5	6	0	0	0	0	11	3,67	21,83	A
Critical standards	10	15	12	7	40	3	1	0	0	0	6	7	0	0	0,5	0	13,5	4,50	26,33	A
Training	10	16	9	9	39	4	1	0	0	0	4,5	9	0	0	0,5	0	14	4,67	31,00	A
Confirmation of process	4	20	10	10	40	4	0	0	0	0	5	10	0	0	0	0	15	5,00	36,00	A
MSL	15	8	11	10	40	4	0	0	0	0	5,5	10	0	0	0	0	15,5	5,17	41,17	A
Presentation	14	10	9	11	40	4	0	0	0	0	4,5	11	0	0	0	0	15,5	5,17	46,33	A
Laser	7	17	10	10	38	4	1	1	0	0	5	10	0	0	0,5	1	16,5	5,50	51,83	A
Confirmation of proceedings (2)	11	10	13	10	40	4	0	0	0	0	6,5	10	0	0	0	0	16,5	5,50	57,33	A
NIM's, procedures and standards	5	15	15	9	39	4	1	0	0	0	7,5	9	0	0	0,5	0	17	5,67	63,00	A
SPI	7	12	15	10	38	4	1	1	0	0	7,5	10	0	0	0,5	1	19	6,33	69,33	A
TPM	0	15	15	14	40	4	0	0	0	0	7,5	14	0	0	0	0	21,5	7,17	76,50	B
Basic module	4	12	12	16	40	4	0	0	0	0	6	16	0	0	0	0	22	7,33	83,83	B
5S circuit	2	10	20	12	39	3	2	0	0	0	10	12	0	0	1	0	23	7,67	91,50	C
SMC	4	6	17	17	40	4	0	0	0	0	8,5	17	0	0	0	0	25,5	8,50	100,00	C
												Total					300			

In Table 3, the first column contains the courses/modules that are taken and in the next two columns, grouped under "Total responses", there are 44 responses distributed among the scales. These numbers are processed by applying the defined weights and the results are presented in the corresponding columns, grouped under "Fuzzy". This way it is possible to perform the summation, calculate the percentages and perform the Pareto classification. It can be observed that the "SMC" course has a higher priority level for the managers' actions. The values of other courses such as "Confirmation of process" or "Laser" could lead managers to decide to plan interventions in these courses to the detriment of others that obtained a higher priority level since they have low values in the smaller scale, and greater distribution in the other scales, which would make interpretation difficult without the aid of the weights. The conclusion obtained with this proposed experience ranking would not be easy to obtain without fuzzy analysis since the distribution of responses alone does not provide an objective measure of evaluation.

5 Recommendations and Final Remarks

Training in the workplace is an important strategy for organizations in the management of human resources because the qualification of the workforce developed externally is often not enough to account for the complexity of certain productive systems, as well as to introduce employees to the decision-making policies and organizational culture. Therefore, in order to achieve effective results, it is necessary that training is understood as a business process, therefore, designed in a horizontally and vertically integrated way, and articulated in the organizational architecture. In this way, the training process becomes a visible structure, from which it is possible to evaluate its alignment with the strategic objectives, and which ensures clarity as to operations, roles, responsibilities, results, expected performance, and therefore its indicators. From this perspective, the evaluation goes beyond the binary criterion of quality and starts to consider different instances in which operations aimed at correcting problems whose effects are immediate and actions that must be taken for the evolution of the process are applicable. In this perspective, the concept of continuous improvement includes in one axis the elimination of defects, and in the other the search for improvement, which means reaching new standards of differentiation. This article aims at this second dimension of quality perception and one found that fuzzy logic can be a suitable instrument for this purpose since it aims to provide means for systems to enable evaluation conditions and decisions closer to the way people think, that is, that do not discard subjective judgments and nuances of perception that are also important, especially in the notion of quality. The prioritization technique, namely the ABC Curve, is presented in this article as a technique for classifying training experiences in order to support the manager in making decisions to obtain results of greater impact on the perception of quality in the training process by its participants.

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Engineering Education Active Learning Maturity Model: a Conceptual Framework

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Abstract

Over the past few decades, the Engineering Education field has undergone a transformation, driven especially by technological advancements and 21st century student's characteristics. The emergence of publications proposing characteristics desired for the "21st century engineer", changes in the accreditation criteria of Engineering courses, several examples of changes in the curricula of Engineering courses throughout the world and the emergence of global initiatives for the modernization of engineering education, such as the CDIO, are the new reality of Engineering Education. In the transformation described, there is consensus in the literature about the need to focus on student learning and to stimulate student engagement. These two aspects are related to the adoption of Active Learning, a growing approach in Engineering courses around the world. Regardless of its popularity, there is no adequate way to evaluate the maturity of adoption of Active Learning in what concerns an institution, a program, or a course. This paper proposes a framework to evaluate the maturity of adoption of Active Learning by a specific course and, because of its aggregation, by a program or institution. The paper presents a literature review that allows identifying its Key Success Factors and the foundations of the maturity model, culminating in the proposed model. The next steps for the construction and validation of this maturity model are presented. In addition to these steps, possible future research and the main challenges identified are addressed.

Keywords: Active Learning; Engineering Education; Conference Information; Project Approaches.

1 Introduction

Since the beginning of the second half of the 20th century, the world has undergone technological changes that have impacted various fields of knowledge. Since the release of the first personal computers, the capacity and speed of data processing have increased exponentially and this has led to a transformation of people, which directly impacted the world of education in general, and the Engineering Education field specifically (Beanland & Hadgraft, 2013; Graham, 2018).

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), in addition to institutions with proposals totally different from the traditional model of the 20th century, such as Olin College (Goldberg & Somerville, 2014) and Aalborg University (Mohd-yusof, Arsat, Borhan, Graaff, & Kolmos, 2013).

With this transformation taking place, one of the main recommendations is to place the student at the center of the learning process. This trend has enhanced the use of Active Learning, a research and practical field that has significantly grown over the last decade. Despite such growth, the literature still lacks a framework to help teachers and administrators evaluate the maturity of adoption of active learning initiatives. Such initiatives can be limited to a specific course or be as general as to embrace the whole educational institution. This work will propose a conceptual model that allows evaluating Active Learning initiatives at the level of a specific course, as this seems logically to be the first step towards a more general and comprehensive model that can evaluate institutions.

2 Methodology

The study begins with a literature review, looking for publications that deal with Key Success Factors (KSF) for the implementation of Active Learning and its variations in Higher Education Institutions (HEI). This review was based on databases Scopus and Web of Science, using keywords related with “active learning” and “engineering education”.

After the selection of publications dealing with this topic, a detailed survey of the identified KSF was carried out, with the aid of the MaxQDA® tool. The research procedures or activities are presented in Figure .

Then, the identified KSFs were consolidated, to group similar items and avoid duplication. After that, each factor had an assumed definition, based on the occurrences found in the literature. The next step was to define the relevant constructs for each factor. And for each construct, the variables that will be used for its measurement.

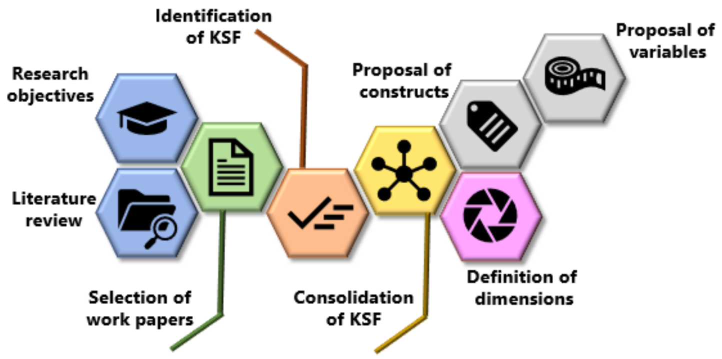

Figure 1. Research procedures

3 Results and discussion

As a result, Engineering Education Active Learning Maturity Model (EEALMM) with 4 levels is showed in Figure 2.

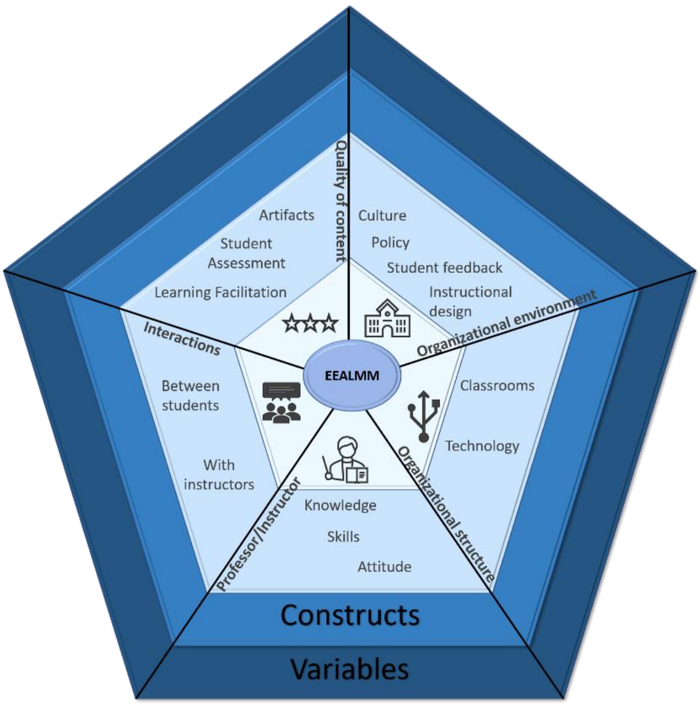

Figure 2. Engineering Education Active Learning Maturity Model (4 levels)

After literature review, 31 works were selected. These works, after consolidation, provided 14 key success factors divided into 5 dimensions, as follows:

- Quality of content (Artifacts, Student assessment and Learning facilitation),
- Organizational environment (Culture, Policy, Student feedback and Instructional design),
- Organizational structure (Classrooms and Technology),
- Professor/instructor (Knowledge, Skills and Attitude), and
- Interactions (Between students and With instructors).

For each KSF, the related constructs were proposed and, for each construct, the variables that will be measured. Each dimension will be detailed in next sections.

3.1 Quality of content

This dimension concentrates the factors related to the core of the learning process, such as the quality of the problems, projects or cases studied (artifacts), the level of difficulty required from the students, whether the activities facilitate learning and whether the evaluation criteria are clear and consistent. The three KSF are detailed below.

3.1.1 Artifacts

Course artifacts should:

- engage students with real-life problems and active experiences (Chen, Bastedo, & Howard, 2018),
- provide students with a variety of additional instructional resources, such as simulations, case studies, videos, and demonstrations (Chen et al., 2018),
- be suitable to achieve different targets including the support of the students' learning process and establishing learning outcomes requirements (Mughrabi & Jaeger, 2016),
- be clearly written, in the right length, useful, flexible, and provide appropriate degree of breath (Shee & Wang, 2008),
- have suitable intellectual challenge (Hegarty & Thompson, 2019; Kuh, 2001; Tomlinson, Evans, & Muijs Daniel, 2015; Zepke & Leach, 2010; Zepke, Leach, & Butler, 2010), and
- begin with an explanation of its purpose (Bacon & Stewart, 2019; DeMonbrun et al., 2017; Donohue & Richards, 2009).

3.1.2 Student Assessment

Student assessment needs to be clear, concise, and consistent. This involves instructions, assignments, assessments, due dates, course pages, and office hours (Chen et al., 2018). Furthermore, criteria for success must be communicated clearly and monitored (Chapman, 2003; Cochrane & Antonczak, 2015; Hattie & Donoghue, 2016; Hegarty & Thompson, 2019; Rutherford, 2010; Tarantino, Mcdonough, & Hua, 2013; Zepke & Leach, 2010).

3.1.3 Learning Facilitation

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 (Mughrabi & Jaeger, 2016). Includes also regular opportunities for formative feedback from professor (Cochrane & Antonczak, 2015; Hegarty & Thompson, 2019; Mesquita et al., 2015; Tarantino et al., 2013; Zepke & Leach, 2010; Zepke et al., 2010).

Table shows the constructs and variables of each KSF defined above.

Table 1. Constructs and variables of Quality of content

Key Success Factor	Construct	Variables
Artifacts	Use of real-life problems	• % of course content based on real-life problems
	Application of active experiments	• % of classes using active methods • Students' perception of hands-on activities
	Variety of instructional resources	• Quantity of instructional resources used • % of classes using resources other than the board or projector • Students' perception of the use of various resources
	Adequacy to Learning Outcomes (LO)	• % of classes linked directly to an LO • Students' perception of reaching an LO
	Suitability of intellectual challenge	• Students' perception of the level of difficulty presented
	Clarity in writing of course activities	• Students' perception of the clarity used
	Size of course activities	• Students' perception of size
	Explanation of purpose of course activities	• Students' perception of clarity in the purpose of the activities • % of activities in which the purpose is explained to students
Student Assessment	Clearness of assessment methods	• Perception of students on the clarity of assessment methods • Are the assessment methods defined in advance? • % of activities that have defined what is expected of the student
	Clearness of criteria for success	• Perception of students on the clarity of success criteria • Are the success criteria defined in advance?
	Communications with students	• Is information about assessment methods and success criteria made available before (or at the beginning of) the course? • Students' perception of communication of assessment methods and success criteria
Learning Facilitation	Preparation of students to conduct activities required	• % of activities flagged as supporting another activity • Students' perception of the existing preparation for conducting activities • Students' perception of the teacher's performance as a facilitator • Intensity of the participation of monitors or auxiliary teachers during the course
	Formative feedback from teacher	• % of activities where there is formative feedback from the teacher • Students' perception of the intensity of support received via formative feedback

3.2 Organizational environment

The factors of this dimension represent abstract aspects of the institution, such as culture, policy, and the practice of collecting feedback from students. These factors have their constructs and variables presented in Table 2.

3.2.1 Culture

Organizational culture is a set of values systems followed by members of an organization as guidelines for behaviour and solving the problems that occur in the organization (Priatna, Maylawati, Sugilar, & Ramdhani, 2020).

3.2.2 Policy

Organization policy is a set of program plans, activities and actions that allows to predict how the organization works and how a problem would be solved (Priatna et al., 2020). Once time is needed to prepare the activities, teachers must have it for implementing something new in their classes (Hernández-de-Menéndez, Vallejo Guevara, Tudón Martínez, Hernández Alcántara, & Morales-Menendez, 2019).

3.2.3 Student feedback

Act of collect feedback from students (DeMonbrun et al., 2017; Francoise, Benay, Kennedy, Semsar, & Bentley, Francoise Judith Benay; Kennedy, Sarah; Semsar, 2011; Yadav, Subedi, Lundeberg, & Bunting, 2011).

3.2.4 Instructional Design

Structure and coherence of the curriculum and the learning material (Brophy, 1999; Paechter, Maier, & Macher, 2010).

Table 2. Constructs and variables of Organization environment

Key Success Factor	Construct	Variables
Culture	Acceptance of changes by the organization	• Ease of approval of pedagogical changes • Ease of approval of administrative changes
	Behaviour alignment	• Clarity of expected behaviours • Existence (or maturity) of behavioural guidelines
	Ability to solve problems	• Perception of the speed with which problems are solved • Perception of transparency in problem solving
	Defining rules	• Existence (or maturity) of a code of ethics
	Adequacy to the rules	• Perception of the existence of punishments for those who violate certain rules
Policy	Organizational support for the preparation of activities	• Perception of the existence of time available for planning new activities • % average of teachers' time in classroom activities • % average of teachers' time in administrative activities • Average amount of administrative functions performed by teachers • Perception of the availability of auxiliary resources for the preparation of activities
	Adequacy of pedagogical plans	• Perception of the adequacy of existing teaching plans to the use of AL
Student feedback	Process of collect	• Existence (or maturity) of the process of receiving feedback from students
	Proper use of feedback collected from students	• Perception of students on the fulfilment of their placements in feedbacks • Number of objective actions resulting from student feedback in the last years
	Quality of the feedback collected	• Is feedback anonymous? • Is the collection in person or remote? • Perception of students about the ease of the process of giving feedback
Instructional design	Structure of the curriculum	• Perception about the adequacy of the curriculum to the needs of the course
	Coherence of the curriculum and the learning material	• Student perception of the alignment of the curriculum with the course material

3.3 Organizational structure

This dimension groups the factors that represent the structure that the organization makes available for the functioning of the activities. Table 3 shows the constructs and variables of each KSF.

3.3.1 Classrooms

Classrooms designed for improve active learning experience (Park & Choi, 2014) and equipped with technologies to enhance student learning and support teaching innovation (Charles, Whittaker, Dugdale, & Guillemette, 2015; Chiu & Cheng, 2017; Chiu, Lai, Fan, & Cheng, 2015; Dori & Belcher, 2005; Soderdahl, 2011).

3.3.2 Technology

Availability, reliability, accessibility, usability of devices, Internet (Wi-Fi), learning support. Inclusive learning environment (AUSSE, 2010; Hegarty & Thompson, 2019; Kuh, 2001; Tarantino et al., 2013).

Table 3. Constructs and variables of Organization structure

Key Success Factor	Construct	Variables
Classrooms	Classrooms designed for improve active learning experience	• Existence of classrooms for Active Learning • Classroom availability for Active Learning • % of activities performed in an environment suitable for Active Learning
	Classrooms equipped with technologies to enhance student learning and support teaching innovation	• Existence of classrooms equipped with multimedia devices and / or laboratories • Availability of classrooms equipped with multimedia devices and / or laboratories • % of activities performed in a technologically appropriate environment
Technology	Availability of technology	• Availability of multimedia devices • Internet availability on campus • Availability of e-learning system
	Reliability of technology	• Reliability of multimedia devices • On-campus internet reliability • Reliability of e-learning system
	Accessibility of technology	• Accessibility of multimedia devices • On-campus internet accessibility • Accessibility of e-learning system
	Usability of technology	• Usability of multimedia devices • Campus internet usability • Usability of e-learning system

3.4 Professor / instructor / teacher

The teacher is the main single actor in a successfully implementation of Active Learning. This dimension group factors that represents their knowledge, skills, and attitude to carry out education innovation. Table 4 shows constructs and variables of each KSF.

3.4.1 Knowledge

Knowledge is a combination of framed experience, values and contextual information that provides an environment for evaluating and incorporating new experiences (Priatna et al., 2020).

3.4.2 Skills

Skills are the ability to use reason, thoughts, ideas and creativity in doing, changing, or making things more meaningful so as to produce a value from the results of the work. (Priatna et al., 2020).

3.4.3 Attitude

Attitude is essentially a human activity, which has a very broad range, including walking, talking, acting, thinking, perception, and emotions (Priatna et al., 2020).

Table 4. Constructs and variables of dimension Professor

Key Success Factor	Construct	Variables
Knowledge	Experience	• Activity time as a teacher • Highest academic title • Time since the highest titration
	Contextual information	• Level of knowledge about Active Learning
Skills	Skills about Active Learning	• Amount of participation in Active Learning events • Number of books read on Active Learning • Amount of Active Learning techniques over which you have mastery
	Skills about educational innovations	• Amount of participation in events on educational innovations • Number of books read on educational innovations
Attitude	Willingness to adopt Active Learning techniques	• Qualitative perception of disposition • Number of periods in which adoption was attempted • Number of subjects in which adoption was attempted • Time since last adoption attempt
	Demography	• Age • Current position • Study area

3.5 Interactions

Placing students at the centre of the learning process requires them to step out of the role of recipients of information and become active agents. The interaction between students and between them and teachers allows this transition to happen. Table 5 shows constructs and variables of each factor.

3.5.1 Between students

Opportunities for students to work together and obtain peer feedback included in the learning design (Hegarty & Thompson, 2019).

3.5.2 With instructors

Interaction between students and instructor supports knowledge construction, motivation, and the establishment of a social relationship (Paechter et al., 2010).

Table 5. Constructs and variables of dimension Interaction facilitation

Key Success Factor	Construct	Variables
Between students	Interactions in general	• Quantity of work / projects carried out in group in the course • % of the grade of the discipline from group work
	Online collaboration	• Number of remote meetings with other students throughout the course • Number of online presentations made by the student with assistance from other students
	Face-to-face collaboration	• Number of face-to-face meetings with other students throughout the course • Number of face-to-face presentations made by the student with the assistance of other students
With instructors	Interactions students/professors	• Number of orientation meetings throughout the course • Number of meetings to monitor projects throughout the course

4 Conclusion

With the advances made in the Engineering Education field in recent years, it has become clear that institutions increasingly need to place the student at the centre of the learning process. As a result, the use of Active Learning has been boosted and has expanded worldwide.

However, the lack of a way of measuring maturity in this regard is a point that hinders evolution. This study proposed a framework to evaluate the maturity of adoption of Active Learning by a specific course. The variables described here can serve as a checklist to teachers adopting active learning and as a metric to evaluate the comprehensiveness and quality of existing initiatives.

As future work, we will: (i) define the measurement method and the scale of each variable; (ii) determine the weights of each KSF in their respective dimensions; (ii) validate the framework as a whole with an international panel of experts; and (iii) test the framework to evaluate the maturity of real cases, which will allow qualitative and quantitative analyses.

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Active learning in project management: the life cycle of a virtual scientific colloquium and its impact on students' performance

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Abstract

The industrial engineering course at the University of Brasilia runs through a project-based learning approach. The course is framed in 12 semesters. In the third semester, a project management discipline prepares students for totally project-based disciplines starting in the fourth semester. Teaching project management and dealing with the complexity of relations involved in the running project with undergraduates that must solve unstructured problems in a short period is challenging. Is it enough to expose the content in lectures? If we had a normal context without the SARS-CoV-2 pandemic, we probably would perform group activities, but it is not possible in pandemic times. After the first half of the discipline, teachers decide to set a virtual project effort to make a virtual colloquium in Project Management. It was a way for students to experience a real project and deal with the diversity of competencies necessary to succeed. The paper presents the discipline structure, the project decisions regarding the endeavor to plan, execute, monitor, and control the Colloquium, and the results regarding student content assessment. Results demonstrate worse grades for the final content evaluation when compared to the first assessment. Despite this, students were satisfied, and the Colloquium was successful with speakers from Brazil and abroad, more than 300 subscribers.

Keywords: Project-based learning; Engineering Education; Project management; Event management; COVID-19.

1 Introduction

In the last 30 years, studies in engineering education have pointed to a change in the educational landscape: away from the rationality that values objectivity, and the linear curriculum focused only on technical learning. This new scenario seeks an educational paradigm that supports the holistic approach necessary for student development (TALGAR, 2017).

Although prior research has shown that active learning can be especially effective for educating a diverse student body while increasing the retention rate of students in STEM (Science, Technology, Engineering, and Mathematics) programs DeMonbrun et al. (2017), in Brazil, most engineering educators do not believe in such methodologies. It is noteworthy that teaching approaches based on lectures remain dominant in engineering education, leaving graduates poorly prepared to understand the complexities of the engineering profession (ASEE, 2009). The lecture-based approach emphasizes procedural knowledge and cannot maintain attention, leading to low attendance rates (MILLS et al., 2003). It means that students may not be motivated to go to class and retain classroom information that emphasizes memorization and recall. It is problematic since memorization, rather than applying knowledge, does not allow students to see what is being taught in the classroom. It contributes to the high dropout rate in engineering courses in Brazil, which is almost 50%, according to the Brazilian Association of Engineering Education (ABENGE, 2018).

Reis et al. (2017) mention several studies that demonstrate the advantages of the results achieved by students using active methodologies. According to Ríos et al. (2010), under an active learning framework, the student leaves the passive role of just receiving the knowledge to take an active role in learning. According to Downing (2001), professional skills are increasingly valued, i.e., companies value skills beyond technical knowledge and specialization. The attempt to innovate in educational practices in Engineering eventually originated new teaching methods around the world. Engineering faculties are increasingly considering the merits of the practical application of knowledge, internalized in the content of disciplines, and before graduation. It is understood as fundamental that engineers develop proficiency beyond technique but include interdisciplinary skills such as cooperation and project management (Taajamaa et al., 2013). In this sense, problem-based learning and project-based learning, both commonly called PBL, have been widely applied as teaching and learning strategies (Lin et al., 2014; Jeon et al., 2014; De Los Ríos-Carmenado et al., 2015; Barbalho et al., 2017).

The University of Brasília (UnB) implemented an innovative undergraduate course in Industrial Engineering in 2009, intending to improve the retention of students' knowledge and better relating theory with practice, adopting a methodology with student empowerment (Prince & Felder, 2006; Lima et al., 2012; Zindel et al., 2012). Based on the PBL approach, the course aims to foster the skills of undergraduate students to deal with real-world problems involved in specific projects that aim to solve a current problem of some company or organization.

This work analyzed a project-based learning activity (PjBL) that integrated the current moment of remote teaching requirement according to COVID-19 with an event proposed within a discipline of UnB's industrial engineering course. A project management colloquium was organized, where the preparation of the entire event was distributed among the students in a team format, maintaining an organization and planning around the project management of the event. In the impossibility of performing face-to-face group activities, the Colloquium allowed students to experience a project with real results, a target audience, responsibilities with stakeholders, time constraints, premises that should be obeyed, and risks to be mitigated.

This paper presents the Colloquium experience and its impact on the students' content evaluations comparing the two tests performed in the discipline. After this introductory section, a chapter presents the main concepts addressed. Section three presents the methodology used in the research. Section four presents the case studied. The article is closed with the final considerations and conclusive elements of stakeholders' perceptions, time constraints, premises that should be obeyed, and risks to be mitigated.

2 Project-based Learning

The Methodology of Project-Based Learning (PjBL) originated in 1959 when the American philosopher and educator John Dewey (1859-1952) proved to learn from the practice of doing, valuing, questioning, and contextualizing the ability of students to think gradually to acquire a relative knowledge to solve real situations in projects related to content in the area of studies (Caldeira et al., 2017). Thus, it is observed that the PjBl is associated with constructivist theories, which aim to allow students to conduct their learning through research and work collaboratively to research and create projects that reflect their knowledge (Bell, 2010). In addition to providing the collection of new viable technological skills until they become proficient communicators and advanced problem solvers, students benefit from this instruction approach (Luz, 2019).

According to Krajcik & Blumenfeld (2000), meaningful learning occurs when the learner actively builds his understanding based on his experience and interaction with the world. Thus, it can be based on the perspective that learning, from basic to graduate education, can be subsidized by a continuous process that will require the student to have a constant reconstruction every time he can acquire and abstract new experiences (Luz et al., 2019).

The learning environment conducted through active methodologies (PBL and PjBL) creates cognitive learning through their actions (Hmello-Silver et al. 2006). For Balve & Albert (2015), the PjBL's approach increases individual motivation and presents students with a real demand that needs to be met. In the PjBL approach, students develop their knowledge through active learning, interactions with the external environment, and teamwork in collaboration, with the complementary guidance of the faculty (Taajamaa et al., 2013). When project-based education covers the entire curriculum, it is called Project-Led Education (PLE) (Lima et al., 2007; Crosthwaite et al., 2006).

There are several studies on the use of the PjBL approach. This learning methodology, covering technical and transversal skills, requires applying skills that can be characterized as "How to do". It is necessary to apply knowledge in practical contexts (Soares et al., 2013). According to the Project Management Institute (2017), the main "soft competencies" for successful project realization are leadership and influence, team building, motivation, communication, decision making, political and cultural awareness, negotiation, trust-building, conflict management, and coaching. Project management literature has demonstrated how critical are these abilities and attitudes in real-world projects (Barbalho et al., 2019; Irfan, 2021).

Previous research at the University of Brasília has demonstrated that students have succeeded when defining their projects' scope (Barbalho et al., 2017). It also points to good knowledge conversion throughout the projects (Reis et al., 2018) with a special focus on soft skills, such as negotiation and teamwork. Luz et al. (2021) also identify teamwork as an important ability in the industrial engineering disciplines at the University of Brasília. The authors also suggest that these experiences deliver better leadership skills and a stronger attitude regarding curiosity and interest in technical contents: these previous research approaches, respectively, production planning and control, and new product development disciplines. The present work is an evaluation of the project management discipline of the Industrial Engineering syllabus.

3 Methodology

This research utilizes a case study approach (Yin, 2001). A deeper analysis is performed regarding an object of investigation, a project management course structured according to the PjBL approach in the virtual context of the COVID-19 pandemic. Qualitative and quantitative data was gathered, the latter using grading datasheets and the former by registering the reflections of the course's faculties, who are also the authors of this study. These reflections were used for understanding the results of the analysis in the form to triangulate data.

The grading data sheet was used to calculate descriptive statistics regarding the case study. A comparison between the students' grades at the initial and final exams, respectively applied before and after the Colloquium, and an evaluation of each student's participation in the colloquium organization and assistance, allow authors to wonder about the practical results of the virtual project-based learning approach applied.

The research hypothesis was that the practical approach of organizing a Colloquium with internationally recognized professionals in project management would motivate students to perform better in the final exam. Once in the first half of the course, the students presented apathy and underperformance.

4 Case Study

4.1 Context

In the Industrial Engineering curricula of the University of Brasília, the PjBL approach is addressed by a set of disciplines called production system design (PSD). Each PSD discipline is related to one or more technical disciplines in a specific semester, and projects are carried out according to the content of their respective anchor disciplines. The discipline involves resolving practical problems of private or public companies with specific project management methodologies (Figure 1). This approach stimulates students' learning by searching for solutions and project proposals to address the concrete issues that afflict partner companies. No technical content is covered before each PSD course. Their anchor disciplines are taught in the form of co-requirement. As the deeper concepts and techniques are commonly programmed for the last classes, students usually learn in a self-taught way. The teacher's support, concepts, and techniques are needed to achieve the design solutions. As every PSD discipline runs as a project, a previous course supports the necessary knowledge for students to plan, execute and control their projects. This discipline is called Production System Design Methodology (PSDM) and is highlighted in Figure 1.

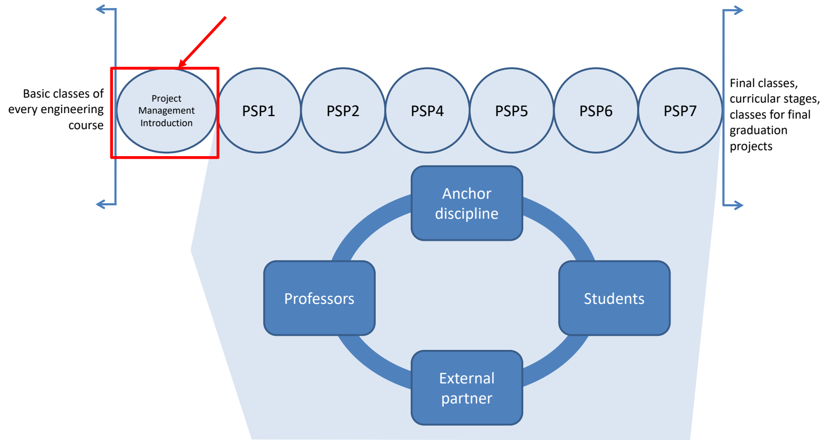

Figure 1. General structure of University of Brasilia's Industrial Engineering program. Adapted form Barbalho et al. (2017).

The PSDM course is related to Project Management (PM). It is the unique mandatory discipline where students face project management knowledge, according to Project Management Institute (2017), as well as theories related to agile project management and organizational project management (Schwaber, 2004; Barbalho et al., 2019). Although the students in the PSDM course are asked to discuss real projects, the course's main focus is theoretical. In 2020 the first semester, the original proposal was built before the COVID-19 pandemic. It was planned to have two exams and a group activity to present PM tools and techniques applied in real-world projects. After the pandemic, the professor planned work only on the theoretical side of the previous plan. Still, after the first exam and joint with the assistant teachers, he proposed a real project to allow students to experience a project by themselves. The best way to do that would be through an event. All students, 55, had to participate as the event staff and also attendees.

4.1 The Project Management Colloquium

The Research Group on Innovation, Projects and Processes (GPIPP) had organized in 2019 the I Project Management Colloquium of the University of Brasília. The concept of the GP Colloquium was to conduct an in-depth scientific discussion on project management in the Federal District, given its potential impact on well-managed projects throughout the country. The Colloquium was thought to be face-to-face, having participated international researchers in GP.

The 2nd Project Management Colloquium maintained the same concept, but it was completely virtual. It had the participation of national and international speakers with great experience in project management and academic research, uniting the scientific world with good management practices. The event gathered in two days more than 350 entries from Brazil and abroad. It supported and participated in project management, education, innovation, and product development, emphasizing the aviation company EMBRAER and the Project Management Institute (PMI) Brazil Chapters.

4.2 Dynamics of Colloquium

The Colloquium aimed to teach the practice of project management to students. A scope and work breakdown structure (WBS) was elaborated up to the work package level by the teacher and his research assistant by way of prior preparation. Next, the WhatsApp tool was used to create workgroups with students. These groups were divided according to the second level of the WBS (the large deliveries to be made). The students there held the meetings to detail the planning and coordinate the division and execution of the work resulting from the delivery (the work packages). A WhatsApp group was also created with all students for general and instant project coordination. For the availability of the scope, WBS, deliveries, and other guidelines of the event's organization, we used the unified platform of communication, collaboration, and file storage, Microsft Teams. All these virtual spaces were monitored and accompanied by the teacher and his assistant. They constantly fed students with new tasks, performed course corrections, and invested in the students' motivation, encouraging the commitment and dedication of each working group.

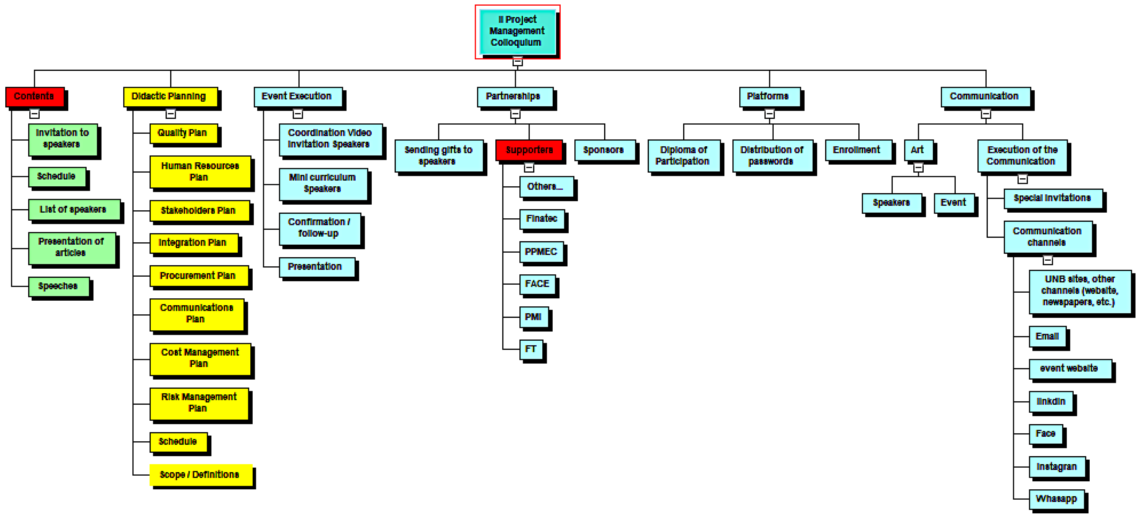

Figure 2. Work Breakdown Structure of Project Management Colloquium

As stated earlier, the conduct of the discipline also took place online, and the videoconferences were held on the Microsoft Teams Platform. The discipline, coordination, availability of didactic content, and notes' availability were held in the Online Platform Google Classroom. In the online classes of the discipline were passed the contents of project management necessary to realize the event and the meetings of Kickoff Meeting, coordination and general monitoring of the project during the class hours were held.

During the week, the event occurred on two days, sequentially, in the evening, between 19:00 and 21:40 hours. The objective of these choices was to allow students' participation, who also attended other subjects during the day. The event had the program presented in Table 1.

Table 1. Colloquium Ageda: Keynotes and Lectures

Colloquium Agenda		
	Keynote	Lecture
DAY 1	André B. Barcaui Post-doctor in Administration from FEA/USP, Ph.D. in Administration from UNR, Master in Management Systems from UFF, with a degree in Information Technology and Psychology. Founding member of PMI Chapter Rio, coordinator of the MBA in Project Management and Information Technology Management at the Getulio Vargas Foundation (FGV).	Agility in project and business
	Prof. Sanderson Barbalho, Ph.D. in Mechanical Engineering from the University of São Paulo, Adjunct Professor in the Department of Production Engineering at the University of Brasília, and coordinator of the Research Group on Innovation, Projects, and Processes (GPIPP).	Project Management Research at UNB
	Júlio Cesar, Program Administrator Engineer of the EMBRAER team, won the PMI award in the USA as the best project of the year 2019.	Requirements Management of the E-jets E2 Program
DAY 2	Darli Vieira (Ph.D.) and Alencar Bravo (Ph.D.) Professors at Université du Québec à Trois-Rivières (UQTR), Quebec, Canadá Research Chair in Management of Aeronautical Projects Chaire de recherche en Gestion de Projets Aéronautiques.	The consolidation of the Chair in Management of Aeronautical Projects.
	Anderson Sales Specialist in Disciplined Agile and Governance Advisor of PMI São Paulo - Brazil.	Requirements Management in the agile look
	Ernani Marques, Partner & founder of ATHEM Consulting and Training, represents the British line of project management, program, and portfolio in Brazil.	PRINCE2 Product-Based Planning

On the day of the event, the professor, his research assistant, and a professional guest ceremonialist held the presentation because of the notoriety and seniority of national and international speakers. However, the entire backstage run was performed by the students. Tasks such as monitoring the speakers, facilitating their access to the tool and removing doubts; the execution of the co-host function in the event of the internet fall of the main host; the support for the solution of technical problems of all order, the control of the access of the enrollees, the monitoring of open microphones to silence them, among others, were all fully implemented by the students.

The event, according to the enrollees and students of the discipline, was a great success. The online form of realization allowed the presentation of an interesting grid of subjects by renowned national and international speakers; allowed the registration of participants from all over the country and abroad, exponentially increasing the number of total entries concerning the first Colloquium. The second Colloquium had more than 300 subscribers. Some lectures registered more than 100 attendees online.

The use of students in the planning and execution of tasks allowed the increase of the project's scope, both in terms of organization but mainly in terms of dissemination and scope. The pedagogical aspect allowed the students to practice theoretical knowledge acquired in project management and senior professionals' access to the project management market. It was made clear among them the feeling of having participated in a really special project/discipline.

4.3 Colloquium evaluation methodology

The Colloquium was evaluated through the participation of students in the activities, and for this purpose, the KAA methodology was used (Luz et al., 2019). The items evaluated and their respective weights are shown in Tables 2 and 3.

Table 2. Evaluated Attitudes

Interest and Curiosity	Evaluate how the student positions himself/herself in his/her engagement in the event. The results of a study commissioned by the Institute for the Future (IFTF) show that all organizations and businesses will be technology-based in the next decade, requiring companies to rethink current models of infrastructure and ways of working (DELL, 2017).
Proactivity	Evaluate the student's ability to effectively resolve (group) deliveries of the proposed project activities. It is adapting the project and following Almeida (2000) perspective that indicates the importance of perceiving the probability of the emergence of a problem before it even happens.
Commitment and Ethics	It consists of evaluating the student's bond with the project, based on Borges' idea (2007), according to which commitment is understood as creating the employees' bond with their respective organizations. This conception can represent the students who remained in the project even though they could lock the discipline and not participate in realizing the project. It consists of the evaluation of Borges (2007) represents the codes of ethics through a set of elements that characterize people's behavior within a social group. In virtual classes, the student's social behavior within the working groups, the unified communication platform, and social media was evaluated.

As illustrated later, the students' attitudes towards the Colloquium were captured through their participation in the event preparation and execution dynamics. Table 3 presents the skills analyzed.

Table 3. Evaluated Skills

Leadership	The ability of the student to exert influence on the group. Khoury (2018) cites a comprehensive list of topics related directly to leadership and indicates communication as the most important tool for exercising leadership.
Teamwork	For Hardingham (2000), in a professional work team, at least one goal can only be achieved by all involved. Here it is about evaluating the student's ability to work in partnership with other team members. Teamwork was evaluated in the performance of activities within WhatsApp working groups, interactions and execution of activities on the Microsft Teams platform, creating and maintaining social media, and conducting/executing the to days of the event.
Collaboration and Cooperation	Collaboration is seen only as of the act of involvement and sharing of information. Cooperation is observed by participation in the group's activities, where the individual is present whenever necessary (ODELIUS, 2016). The student's performance was evaluated during the kickoff meeting, follow-up meeting, end-up meetings; in the working groups on WhatsApp and during the event, together with the group, interacting in the activities carried out are examples where collaboration and cooperation between students could be evaluated.

Communication	Today there are specific methods to conquer the space increasingly idealized by creative communication that meets the most varied needs in the universe of human relations (PONTE, 2000). Here, it evaluates the student's ability to clarify doubts with their questions and answers when questioned. Ability to organize ideas when talking about deliverables' progress, communicate on social networks, workgroups, and open spaces for questions during the event.
Critical Analysis	Evaluate the student individually regarding their critical perception (evaluative) about the stages of the project and the decisions made by the team. Students who resist express themselves or who do not contribute to their group may find it difficult to give opinions.

The following constructive aspects of the Colloquium were used to identify the students' skills and attitudes regarding the event:

- Participation in the Colloquium (event), as a spectator or working in the assistance of some activity;
- Participation in meetings in the virtual classroom. Learning content, taking questions, as well as performing status presentations of project deliveries;
- Performing deliveries of activities, whether planning, organizing, or executing the Colloquium. Effecting the delivery;
- Participation in WhatsApp groups for coordination and development of deliveries;
- Registration in the social networks created for the event (event website, Whatsapp, Facebook, Instagram, Linkedin).
- Participation and performance (dissemination, interaction, posts) on social networks of dissemination of the event (event website, WhatsApp, Facebook, Instagram, Linkedin);
- Participation in the unified communication and collaboration platform (Microsoft Teams) for the coordination, registration, and realization of deliveries

Table 4 lists the attitudes and skills analyzed to infer the Colloquium students' participation score with the evaluation moments presented above.

Table 4. Applied Evaluation Model of the PSDM Discipline in 2.2020.

		(1) Participation in the Colloquium (event)	(2) Participation in meetings in the virtual classroom	(3) Realization of the Deliveries of activities	(4) Participation in WhatsApp groups	(5) Registration on the social networks of the event	(6) Participation and performance in the social networks of the event	(7) Participation in the Microsoft Teams platform
Attitudes	Interest and Curiosity							
	Proactivity							
	Commitment and Ethics							
Skills	leadership							
	Teamwork							
	Collaboration and Cooperation							
	communication							

The next section presents an analysis of the grades obtained by the students in this teaching and learning process, considering the 1st test performed by the students in which the classes were positive using a virtual environment, the final score of participation of the Colloquium, and the grade of the final test of the discipline.

4.4 Results

Table 5 presents the descriptive analysis of the students' grades.

Table 5. Final grades

	Exam 1	Attitudes	Abilities	Colloquium	Exam 2
Average	6,84	8,40	7,72	9,06	5,94
Standard deviation	2,10	1,76	1,72	1,59	1,79
Maximum	10,00	10,00	10,00	10,00	9,70
Minimum	2,40	1,00	1,00	0,00	2,70

As presented in Table 5, the second exam had fewer grades than the first one, even after the workgroup represented by the Colloquium. Table 6 presents the correlations between these data.

Table 6. Correlation between grades

	Exam 1	Attitudes	Abilities	Colloquium	Exam 2
Exam 1	1				
Attitudes	0,043	1			
Abilities	0,016	0,958	1		
Colloquium	0,214	0,877	0,844	1	
Exam 2	0,333	0,146	0,212	0,134	1

As presented in Table 6, there was no correlation between exams and the Colloquium results. The Colloquium grade is only associated with the attitudes and skills analyzed.

5 Discussion and Conclusion

This paper presents a case study where a virtual team practice was proposed in a Project Management discipline. Still, no results were realized regarding a better knowledge apprehension by students, as captured in an exam, and the attitudes or abilities diagnosed as highlighted in the case.

This result was not expected but brought reflections concerning project-based learning approaches regarding students' knowledge in these educational practices. The fact is that the second exam had as a focus some techniques for project management planning and control, especially for scope and time management. Then, the most worked skills and attitudes that the teaching group implemented for training students and the planning and execution of PM colloquium were not evaluated on the second exam. Instead, the exam was technical-based, developing well-done work breakdown structures and critical path analysis. These contents belong to the hard part of PM knowledge.

For more consistency to evaluate a project like this, it could be better to assess the students' motivation after the first and second parts of the discipline. Some questions on the second exam could be addressed to evaluate if the practice of PM Colloquium has reinforced any soft skills evaluated on the first exam. Finally, the Colloquium could be prepared actively using work breakdown structures and project schedules to align it with the technical content taught in the second part of the PSDM course.

Future studies will analyze the following Colloquiums and improve the data gathering approach, not only in attitudes and abilities but also the knowledge element of the KAA framework. The same content of the PSDM discipline will be applied without the PM Colloquium to advance reflections on the impact of virtual project-based learning on engineering education.

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Teaching innovation: comparison between project-based and traditional learning approaches

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Abstract

Innovation is a multi-faceted thematic. It ranges from economy to engineering, from management to technology development, from knowledge management to manufacture. Besides, innovation involves changing mindset and a multitude of cultural issues which can hinder its progress. Concurrently, engineering courses face a reality in which there is no specific discipline of innovation in their syllabus. According to the new technologies, the Brazilian government has started a national effort to update the engineering curriculum and challenges engineers will deal with in their professional practices. This paper presents the experience of the discipline "Innovation of Production Systems" at the University of Brasília. From 2013 to 2020, the discipline has experienced variations with different theoretical content levels, problem-based learning assignments, or contextual-based discussions concerning the markets and innovation ambients in Brazil and abroad. By analyzing the evolution of discipline content, the amount of problem-based learning demanded, the final grades, and qualitative results, we reflect on teaching innovation and having significant results beyond the own academic grades. Two hundred twelve students demonstrate that practical assignments arouse more interest from students, but the impact was irrelevant. Results suggest that the workload of innovation in engineering undergraduate courses needs to be improved from an entrepreneurial perspective.

Keywords: Innovation; Problem-based learning; Engineering Education; Entrepreneurship.

1 Introduction

Given the current dynamics of the economy, companies have invested in their innovative capacity. Companies have sought new engineers with training about the innovation process and have invested in incorporating graduates with this profile in the daily business. Among the models with greater market penetration stand out for their apparent ease of understanding, the Innovation Funnel proposed by Wheelwright and Clark (1992) and the stage-gate model© proposed by Cooper (2011). These and other innovation models such as lean startup or disruptive innovation need to be taught to engineering students.

According to Resolution No. 1/2019 of the Higher Education Chamber/National Council of Education CNE/CES (Brasil, 2019), the industry sector finds it is difficult to recruit skilled people to work on the frontier of knowledge. Professionals with leadership skills, teamwork, strategic planning, and management skills, the so-called soft skills. Moreover, engineers must deal with entrepreneurship concepts in a positive way (ABENGE, 2018).

It is noteworthy that teaching approaches based on lectures remain dominant in engineering education, leaving graduates poorly prepared to understand the complexities of the engineering profession (ASEE, 2009) and entrepreneur endeavors. Borrego et al. (2014) mention several studies that demonstrate the advantages of the results achieved by students using active methodologies. According to Ríos et al. (2010), under an active learning framework, the student leaves the passive role of just receiving the knowledge to take an active role in learning. According to Downing (2001), professional skills are increasingly valued, i.e., companies value skills beyond technical knowledge and specialization. According to Borrego et al. (2014), a multiple set of experiences demonstrate the effectiveness of the PBL approach to teach soft skills in many engineering areas. However, few studies present comparisons of traditional and PBL practices in one specific discipline.

According to Barbalho et al. (2017), the University of Brasília is developing its industrial engineering program, a set of active learning experiences. Some evaluation efforts have been made by researchers, approaching content apprehension (Reis et al., 2018) and general satisfaction (Zindel et al., 2012). In this context, this paper aims to present the results of their experience in one specific course, termed Production System Innovation (ISP). This course is taught as a non-mandatory discipline, and project-based teaching varied over the semesters. There was the exclusive use of an approach based on exhibition classes and exams. We intend to explore this variation and its impact on students' grades.

In the next section, our theoretical basis is presented, and after the research methodology. Section four presents the case study. In the end, the main discussions and remarks are highlighted.

2 Innovation

The theme of innovation has been widespread in recent years, but its initial conceptualization dates back to the beginning of the last century. According to Schumpeter (1982), modern society is based on economic transformations of an evolutionary character. Its operation is driven by new methods of production, transport, new markets, and new forms of industrial organization. This condition revolutionizes the economic structure from the inside out, destroying the old and creating the new, which characterizes innovation.

Also, according to Schumpeter (op. cit.), innovation is possible due to the role of the innovative entrepreneur. Its function would be to change the production pattern, using a new idea to produce a new product, or produce it differently—Dyer et al. (2012) detail the characteristics of the innovative entrepreneur. The authors interviewed inventors of revolutionary products and services, founders and managers of companies considered innovative and realized that some skills were detained in their work process.

Christensen (2012) calls the innovator's dilemma that rational decision-making – based on execution skills – implies the difficulty many leading companies have had to maintain a hegemonic competitive position. These companies have faced breakthrough innovations, whose logic of competition differs significantly from the technological environment before them since such innovations give rise to and continue through the constitution of new value networks in unprofitable niches for established companies. These networks are driven to the most profitable environments as the advancement of rupture technologies consolidates technically and operationally.

To manage innovation, Wheelwright and Clark (1992) developed the idea of an innovation funnel. The "funnel" is a graphic representation that exemplifies the innovation process. At the funnel, entrance is the proposals for innovation, which are ideas of products to be evaluated. At the end of the funnel, we have products and services that have been selected and will be launched on the market. Throughout the funnel, the applicable market conditions and technology are considered for decision-making of the feasibility of each product and due selection, which will remain in the development process. The authors warn that one of the main difficulties of innovation is the structuring of a process that allows capturing many ideas, but that over time is frozen or finished projects that do not meet the criteria of success of the company.

The procedural aspect of innovation has been the focus of several studies. It has been consolidated in the format of works such as Barbalho and Rozenfeld (2013), which inserts several concepts of process management and knowledge of areas related to product and factory engineering. Commonly, these models present stage-gate structure©, as proposed by the seminal works of Clausing (1994) and Pugh (1990). However, it is important to mention that the development funnel is usually referred to as the stages of the innovation process that the literature has agreed to call fuzzy front end (FFE). The FEE is an allusion to the fact that the initial stage of the innovation process is the locus of the most creative activities, the proposition of the new business, new products, and services with the promotion of divergent thinking (KOEN, 2005).

3 Problem-Based Learning

The Methodology of Problem-Based Learning (PBL) proved to learn from the practice of doing, valuing, questioning, and contextualizing the ability of students to think gradually to acquire relative knowledge to solve real situations in the area of studies (Caldeira et al., 2017). Thus, it is observed that the PBL is associated with constructivist theories, which aim to allow students to conduct their learning through research and work collaboratively to research and create projects that reflect their knowledge (Bell, 2010).

According to Krajcik & Blumenfeld (2000), meaningful learning occurs when the learner actively builds his understanding based on his experience and interaction with the world. Thus, it can be based on the perspective that the learning development, from basic to graduate education, can be subsidized by a continuous process that will require the student to have a constant reconstruction every time he can acquire and abstract new experiences (Luz et al., 2019).

The learning environment conducted through active methodologies creates cognitive learning through their actions (Hmello-Silver et al. 2006). For Balve & Albert (2015), the PBL's approach increases individual motivation and presents students with a real demand that needs to be met.

There are several studies on the use of the PBL approach. This learning methodology, covering the construction of technical and transversal skills, requires applying skills that can be characterized as "How to do"; that is, it is necessary to apply knowledge in practical contexts (Soares et al., 2013).

Previous research at the University of Brasília has analyzed the production planning and control discipline (Barbalho et al., 2017). It points to good knowledge conversion throughout the projects (Reis et al., 2018), focusing on soft skills, such as negotiation and teamwork. Luz et al. (2021) also identify teamwork as an important ability in the industrial engineering discipline of new product development at the University of Brasília. The authors also suggest that these experiences deliver better leadership skills and a stronger attitude regarding curiosity and interest in technical contents. However, this previous research didn't detect content apprehension along with the training process of soft skills. The present work is an evaluation of the innovation discipline of the Industrial Engineering syllabus.

4 Methodology

This research utilizes a case study approach (Yin, 2001). A deeper analysis is performed regarding an object of investigation, an Innovation course flexibly structured in the PBL or traditional approach. Qualitative and quantitative data was gathered, the latter employing grading datasheets and the former by registering the reflections of the course's Professor.

The grading datasheets stored data from the first semester of 2013 until the first semester of 2020, totaling 212 students, generating a specific datasheet each semester. These were analyzed and formatted, consolidated into a single document containing all individual and group activities and their respective grade summaries. A binary classification was considered for each activity used in the students' evaluation, namely "1" when the activity composed the evaluation datasheet or "0" when it was not. Statistical analysis was then conducted regarding the contents and grades for every student, and it is presented here.

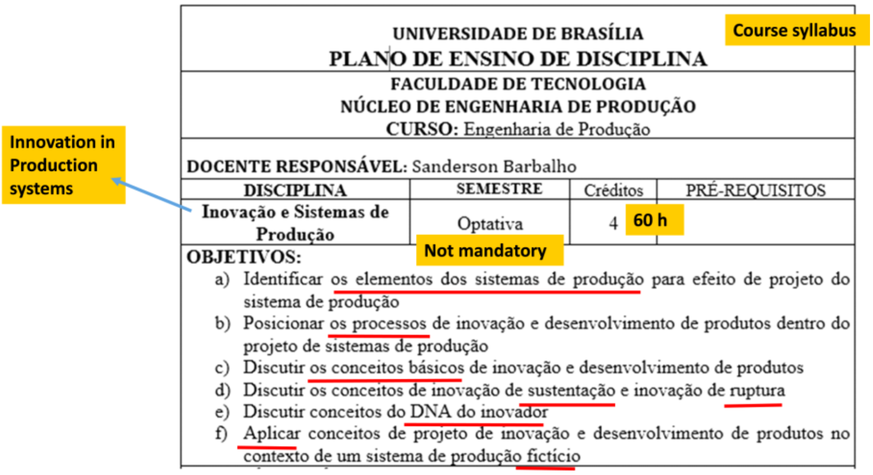
5 Case Study

5.1 The Production System Innovation discipline

Figure 1 presents the main elements to characterize the Production System Innovation discipline here analyzed.

The course is part of the Department of Industrial Engineering belonging to the Faculty of Technology of the University of Brasilia, located in Brasilia, capital of Brazil. It is an optional course - not mandatory - that students from different faculties can take, and over the years 2012 to 2020, it was taught by the same teacher. The workload of this innovation course is four credits, which is translated into 60 hours, and it does not have other courses as a prerequisite, allowing students from different areas to have access to this important theme.

Covering the most relevant points of the subject relies on the possibility of student diversity. The objectives sought throughout the activities performed in the course are: to identify the elements of production systems for the production system project; to position the processes of innovation and product development within the production system project; to discuss the basic concepts of innovation and product development; to discuss the concepts of sustaining innovation and disruptive innovation; to discuss the concepts of innovator DNA and to apply concepts of innovation project and product development in the context of a fictitious production system.


UNIVERSIDADE DE BRASÍLIA
PLANO DE ENSINO DE DISCIPLINA
FACULDADE DE TECNOLOGIA
NÚCLEO DE ENGENHARIA DE PRODUÇÃO
CURSO: Engenharia de Produção

DOCENTE RESPONSÁVEL: Sanderson Barbalho

DISCIPLINA	SEMESTRE	Créditos	PRÉ-REQUISITOS
Inovação e Sistemas de Produção	Optativa	4	

OBJETIVOS:

a) Identificar os elementos dos sistemas de produção para efeito de projeto do sistema de produção
b) Posicionar os processos de inovação e desenvolvimento de produtos dentro do projeto de sistemas de produção
c) Discutir os conceitos básicos de inovação e desenvolvimento de produtos
d) Discutir os conceitos de inovação de sustentação e inovação de ruptura
e) Discutir conceitos do DNA do inovador
f) Aplicar conceitos de projeto de inovação e desenvolvimento de produtos no contexto de um sistema de produção fictício

Figure 1. Course syllabus

Figure 2 presents the contents of the Production System Innovation discipline from the first offer to the latter. In the first semester, the discipline focused on production system literature and innovation origins, especially concerning Schumpeter's discussion of creative destruction. A production system had to be analyzed, and the students had only one exam.

In the second semester, more content regarding innovation was inserted, including case studies of innovative companies, an activity to publish innovation news on a Facebook page, and a proposal to innovate in the previously analyzed production system. The same structure was replicated in the third semester. It provided more time exposure of students to the innovative concepts in practice. Starting in the fourth semester, the Professor suggested students start a business. Firstly, a business based on the Facebook platform, but since the fifth semester, a technology-based business. This proposal was compensated by getting off the syllabus the study of an existing production system. The Professor, intending to help students start a new business, added a more structured theoretical discussion regarding business model generation since the seventh semester. One of the exams was also removed from the syllabus.

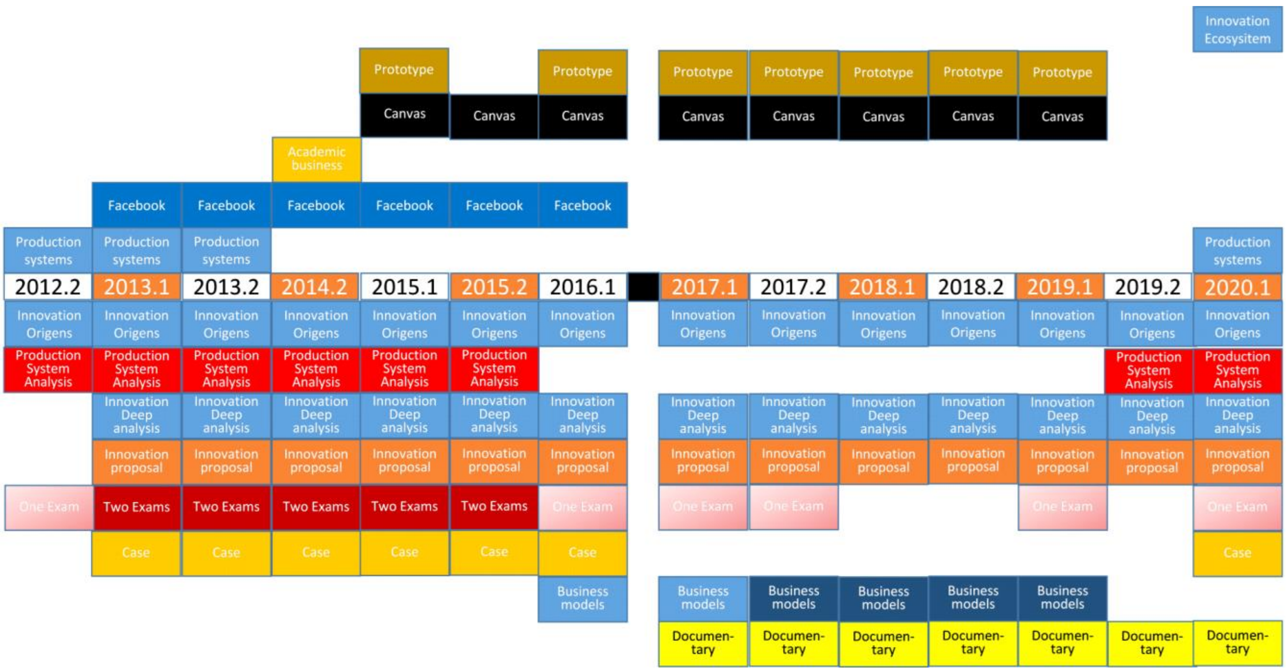


Figure 2. Content variation among ISP classes

From the eighth to the twelfth offer, more business model innovation theories were inserted. The Professor even eliminated the exams and inserted documentaries on new ventures, disruptive technologies, and past magnates of innovation to motivate students to propose good business models and work on the first conceptual prototypes. Almost 40 business models were generated, but only one startup was generated, with the students giving up fast. After reflecting on these results, the Professor found that a focus on business generation should be based on a deep study of existing production systems and good reasoning about how innovation can disrupt a production system.

These reflections impacted the change of the discipline syllabus in which the business model generation got off, and more theoretical content and exams were reinforced. This change is in course nowadays, and the statistical analysis here reported is part of this redefinition.

5.2 A review of students who concluded ISP

This section presents the results of the statistical analyses performed using the SAS® software. Based on the assessment records made between 1/2013 and 1/2020. Of the 219 initial records, seven students who had no assessment records (missing values) were unconsidered, i.e., they left the course, so they had no performance in the subject. In the evaluated period, the average grade of the students was 7.55 with a standard deviation of 1.59. It was also verified that the lowest score recorded was 1.01, and the highest was 9.90, indicating a large amplitude of scores, as shown in Figure 3, the boxplots of the students' final scores year of assessment.

From Figure 3, it is evident that the evaluation criteria adopted in the years 2017 and 2018 resulted in higher variation of grades among students. The period already mentioned where theory was decreased to focus on business model creation. On the other side, in 2016, the best grades among students were verified and the lowest variation of grades. This class has significant innovation activities, analyzing case studies in the classroom and the Facebook activities. It also had the only startup generated from the business models in the classroom.

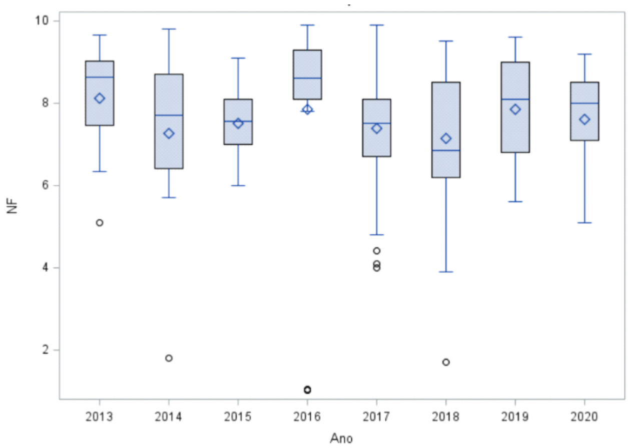


Figure 3. Final scores of the students per year

A Multiple Linear Regression was performed from this initial exploratory analysis to identify the variables that present significant effects to explain the students' final grade (FG). From the whole set of ISP instances, 43 different evaluation forms were identified and submitted for regression analysis on the fourteen times it was offered. Whose the general linear model is presented in the following expression:

$$Y = X\beta + \varepsilon$$

where X is the matrix composed of binary variables relative to the evaluation mechanisms used in the period above, β is the vector of unknown parameters, and ε is the vector of unobservable model errors. The model assumptions were tested and validated.

Table 1 presents the results related to the Analysis of Variance, indicating that the adjusted model presents a coefficient of determination R2 = 0.9624, which explains approximately 96% of the variation found in the dependent variable (FG).

Table 1. Analysis of Variance

Source of Variation	Degrees of Freedom	Sum of Squares	Average square	*F*	P-value
Model	8	12130	1516.30	653.08	<0.0001
Residues	204	473.64	2.32		
Total	212	12604			

The Stepwise method was used to fit the model. The selection of covariates that remained in the model was progressive, with the removal of covariates whose effects were not significant (p-value > 0.05). Table 2 presents the covariates that presented significant effects to explain the variation of the dependent variable (FG).

Table 2. Stepwise Method Fitted Model

Covariate	Estimated Parameter	Standard Error	*F*	*P-value*
Production System Analysis (X_1)	9.01823	0.71939	157.15	<0.0001
Group activities (X_3)	9.34561	0.47013	395.17	<0.0001
Economic evaluation of business models (X_{12})	-1.96667	0.42460	21.45	<0.0001
Prezi case study (X_{24})	8.12333	0.35915	511.59	<0.0001
Pirates of Silicon Valley movie (X_{34})	-17.79395	0.80562	487.85	<0.0001
One Exam (X_{35})	-1.40395	0.43110	10.61	0.001
Engagement evaluation (X_{36})	1.33252	0.67618	3.88	0.050
Final Presentation (X_{43})	7.60000	0.32486	547.31	<0.0001

The variables presented in Table 2 allow us to infer that production system analysis is a significant element in the final grades. Group activities and case studies have a significant impact. But the utilization of the movie Pirates of Silicon Valley negatively impacts final students' grades. Having Only one exam is not good for grades, neither is asking students to perform an economic evaluation of their business models. The final presentation and the analysis of students' engagement in the course also impact the final grades.

Based on the coefficients of the adjusted model. It is possible to verify the increase or decrease in the estimates of the final grades resulting from the covariates used as instruments for student assessment, as presented in Table 3.

Table 3. Estimates and Simulations of Final Scores given the Selected Evaluation Criteria

Covariates	X_1	X_3	X_{12}	X_{24}	X_{34}	X_{35}	X_{36}	X_{43}	*FG*	*Error rate (%)*
Year/Coefficients	9.02	9.35	-1.97	8.12	-17.79	-1.40	1.33	7.60		
2013_1	0	0	0	1	0	0	0	0	8.1	6.0
2013_2	0	0	0	1	0	0	0	0	8.1	-10.4
2014_2	0	1	0	1	1	0	0	1	7.3	-0.3
2015_1	0	0	0	0	0	0	0	1	7.6	-1.3
2015_2	0	0	0	0	0	1	1	1	7.5	0.4
2016_1	0	1	0	0	0	1	0	0	7.9	-0.6
2017_1	0	1	1	0	0	0	0	0	7.4	-1.2
2017_2	0	1	1	0	0	0	0	0	7.4	0.9
2018_1	0	1	1	0	0	1	0	0	6.0	-0.3
2018_2	0	1	0	0	0	1	0	0	7.9	1.1
2019_1	0	1	0	0	0	1	0	0	7.9	1.2
2019_2	0	0	0	0	0	0	0	1	7.6	0.8
2020_1	1	0	0	0	0	1	0	0	7.6	0.1

According to Table 3. it is possible to see that the variables from the regression model can explain under a 2% error rate the average grades of every ISP class.

6 Final Considerations

Innovation is a theme to support new engineering courses. The new industrial revolution brings a more challenging environment for new engineers. This paper presented an innovation discipline whose variations on the content and evaluation method were gathered and compared.

We see those project-based learning elements, such as group activities, presentations, case studies, significantly impact the final grades. We also find that traditional methods impacted suggesting a necessary balance between engineering tradition and new engineering education methods.

Additional protocols could be applied to evaluate the discipline results for alumni, especially if they are working on the innovation subject if the course impacted this professional choice. A model for predict good students' results was generated, and new research protocols can apply it to new ISP classes for validation and analysis.

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Exploring blended learning tools to transform a laboratory course unit in engineering: challenges, setbacks and rewards

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Abstract

To boost students' engagement on learning outcomes, promote active peer learning, and adopt more dynamic teaching practices, a module of a laboratory course unit (TPL) in engineering was reformulated exploring blended learning. This reformulation was even more challenging than initially anticipated as it was implemented during the Covid-19 pandemic. As TPL learning practises are based on the operation of laboratory modules mimicking heat and mass transfer phenomena, asynchronous and on-line synchronous learning classes and face-to-face laboratory classes were outlined. To promote the asynchronous learning, a full script of TPL and pitch and longer videos presenting, respectively, each work and its practical operation process were formerly prepared and available online. Students were required to work in group to define the variables and conditions to be evaluated in each laboratory module, organize and plan the experimental activities, create data recording documents, and later present and argue their options in virtual synchronous classes. In the face-to-face classes, different activities were performed in a rotating system, scheduled and tuned in the online classes. It was also aimed in-situ promoting peer discussion of the data and reports elaboration, goals not attained due to the pandemic restrictions, as only two students of each group were present in each hands-on class and in sequential times. TPL reformulation was a tough and time-consuming task since 73 students were enrolled, divided into 3 shifts, each one with 5 groups of five students. Students individual learning evolution was inferred through online quizzes that were periodically made available. A final inquiry, launched to obtain students` opinion about this transformation endeavour highlighted the script, videos, and the prompt teachers' feedback on the reports as the most fruitful and important aspects for students' engagement and guide their learning pathway. The rationale behind this paper was to disclose this transformation experience and share information and strategies that can be used in the teaching/learning of laboratory classes.

Keywords: Blended Learning; Engineering Laboratory Courses; Pitch videos; Collaborative learning

1 Introduction

Laboratory classes provide students with a first-hand experience within the concepts of the theoretical lectures and the opportunity to explore the methods used by scientists in that courses. Therefore, the laboratory is as important as the theoretical and conceptual knowledge. In the engineering lab classes, students deepen scientific subjects in an effective way; apply concepts learned in class to new hypotheses, learn to use scientific devices, learn to estimate statistical errors and recognize systematic errors. In addition, it improves students' work skills, such as reporting skills (written and oral), skills in collecting, analysing, interpreting and presenting findings and data, the development of critical and quantitative thinking; the learn to work in group, and allows to exercise curiosity and creativity when designing a procedure to test a hypothesis (National Research Council, 1997). For this, the students define the variables and conditions to be evaluated, organize and plan the experimental activity, create data recording documents, then perform the experiments according to a laboratory protocol, and, at the end, analyse the data and interpret the results. Thus, the laboratory classes play a fundamental role in teaching engineering as they provide a valuable opportunity to understand, apply and investigate theoretical concepts, practise a wide range of personal and transferable skills, such as problem solving, team working, observing and following protocols, and the development of several individual competencies. It also helps students to work more effectively and safely in a laboratory space understanding the storage and handling of hazardous materials, safety guidelines and safety labels (Artdej, 2012).

Laboratories of Transport Phenomena and Materials (TPL) is a course unit offered to the third year students within the Integrated Master in Biomedical Engineering, University of Minho. This laboratory course intends to provide to the students' capacities to understand and perform laboratory work in the areas of fluid mechanics and heat and mass transfer. In the 1st semester, this course unit comprises two laboratory modules, each one under the responsibility of different departments of the School of Engineering of University of Minho. One of the modules, under the responsibility of the Department of Biological Engineering (DEB) addresses a series of practical works covering heat and mass transfer-related phenomena. The main theoretical fundamentals, concepts and knowledge base were previously presented to the students in the scope of other course units.

In recent years, with the advent of integrative technologies, it has been reported that the capacity to support effective laboratory preparation can be more readily implemented allowing students to prepare lab classes in their own space and time. Indeed, it is now well-assumed that this approach often builds in students a greater capacity to address pedagogical learning diversity (Patterson, 2011; Jones & Edwards, 2010; Di Trapani & Gregory, 2009; Chittleborough et al, 2007). With this kind of approaches, it is expected to make learning more attractive and that students will have a greater commitment and obtain a better performance. With these new educational concepts in mind, the idea of reformulating the DEB module of this laboratory course unit in engineering grew and took shape by exploring these new integrative forms of learning. Amid the reformulation, Covid-19 emerged worldwide bringing with it some new and unexpected setbacks that forced to speed up the process of transformation and include some new teaching and learning practices, to face the restrictions dictated by the pandemic situation. As initially delineated, the traditional classes were converted in to face-to-face and online formats (Oyedotun, 2020) exploring blended learning tools.

The Covid-19, an infectious disease caused by the SARS-CoV-2 virus, was firstly identified in China, in the beginning of 2020, but rapidly spread all over the world, with the World Health Organization declaring it as a global pandemic. Covid-19 had and continues to have a negative impact on many sectors including health, industry, trading, agriculture, education, among others (Oyedotun, 2020). In addition to the impact caused by coronavirus pandemic in people's normal lifestyle, it had a profound effect in education forcing the suspension of in-class activities, the quick adaptation to non-face-to-face classes and the use of technology (Jain et al., 2021; Oyedotun, 2020) to support the continuity of teaching and learning. Indeed, the Covid-19 impact in Education resulted in the closure of schools and educational facilities, affecting over 900 million of students worldwide (Unesco 2020). All these measures were adopted aiming the prevention of the spread of the disease (Lockee, 2021). E-learning has thus become the rule of the covid-19 outbreak (Karp and Mc-Gowan, 2020).

As a great number of universities worldwide, University of Minho, in the context of Covid-19 pandemic, was forced to interrupt its normal teaching activities and move towards, in a first stage, to totally non-face-to-face, classes, and later to hybrid teaching models. Accordingly, the entire laboratory classes were transformed into online and blended classes.

Therefore, this paper aims to share to teachers and students and discuss some measures and strategies adopted in the scope of the reformulation of TPL, a laboratory course unit in engineering, exploring more dynamic teaching practices attempting to engage students in the learning outcomes and improve active peer learning. This transformation was even more challenging as its implementation took place coincidentally during the Covid-19 pandemic. Hence, the rationale behind TPL transformation and their advantages, limitations and recommendations are highlighted, as well as the feedback of students regarding this transformation endeavour.

2 Blended learning tools

A module of a laboratory course unit of engineering, TPL, was reformulated exploring blended learning strategies. Blended learning is highlighted throughout the educational resources as a major curriculum design method for improving students' motivation and the acquisition of knowledge via a student-centred approach (Benn, 2019). Blended learning tools combines both real-time in-class (and/or in-lab) activities and online ways of teaching. The latter can be accomplished in asynchronous and synchronous learning classes. In the TPL reformulation, asynchronous classes were implemented to allow students, in their own space, time and pace, to gain knowledge about the works to be later developed and prepare the lab classes by reading the TPL script (containing the description of the laboratory works, their theoretical fundamentals and practical aspects), visualization of pitch videos (2 min) and longer videos (10 min) presenting, respectively, each laboratory work and its practical operation process. These educational materials were formerly prepared and made available online for student's timely access. Indeed, pitch videos disclose a general explanation of each laboratory module mimicking heat and mass transfer phenomena (e.g. different types of heat exchangers) and a brief description of how they work. Longer videos exemplify the practical operation of each laboratory work that students will run into, calling attention to the particularities of each work and the possible conditions for analysis. After the individual examination of the educational materials, students were required to interact with each other in team work in order to share their own knowledge and interpretation of the information provided, define the variables and conditions to be evaluated in each laboratory module, organize and plan the experimental activities, create data recording documents, and later present and argue their options in virtual synchronous classes. The synchronous sessions, scheduled through Blackboard and Colibri Zoom platforms, also allowed the close contact and interaction between teachers and students and also served to clarify any doubts, namely, those regarding the laboratory modules, the theoretical concepts supporting each work and the pre-prepared documents to collect the experimental data and discuss with teachers and colleagues the variables to be studied to attain the goals defined for each laboratory work. Extra synchronous classes were held whenever requested by students.

In the face-to-face in-lab classes, 5 different laboratory activities (equal to the number of groups enrolled in each shift) were performed on a rotating basis, scheduled and tuned in the online classes. Due to laboratory space limitations and to comply with the guidelines of the World Health Organization and the good safety rules imposed by the Covid-19 pandemic crisis, the number of students attending the practical classes at the same time had to be drastically reduced which led that, in each in-lab class, only two elements of each group, in sequential times, operated alone the laboratory modules. Consequently, each student only executed, in person, two of the five practical works proposed in the DEB module. Even though, it must be highlighted that with the rotating system for carrying out the different works, all the students had the opportunity to have contact with the laboratory facilities and the lab modules mimicking the heat and mass transfer phenomena. Even operating the lab works individually, all students were encouraged to work in group when performing the treatment and analysis of the experimental data and the discussion of all proposed works, being mandatory to do, weekly, a mini-report, containing the following sections: abstract, main results presentation, data discussion and main conclusions. Teachers feedback on these results reports was communicated to students in the face-to-face class immediately after the practical work class. With this effort of timely reading and critical analysis of the reports, teachers attempted that the weaknesses and the less well achieved aspects, both in terms of form and content, could be improved and the constructive suggestions included in the following mini-reports. Additionally, in scheduled synchronous extra classes some quizzes were available for students individual learning self-diagnosis.

After running into all the laboratory activities, all groups were required to do a whole report about one of the laboratory modules carried out along this course unit, encompassing data collected by all the groups in each shift in order to stimulate knowledge sharing between groups and allowing the discussion of a wider range of variables and conditions. This strategy was an attempt to overcome the lack of sharing and discussion of information initially expected to occur among students during the face-to-face in-lab classes. Teachers opinion about the whole reports was also communicated to students.

At the end of the semester, a final in-class written evaluation test covering all the subjects explored in each of the laboratory works performed throughout the PTL course unit was carried out. In addition to all the aforementioned elements of evaluation, the students interest, preparation and performance in the face-to-face in-lab classes were also registered and appreciated by teachers.

3 Challenges, setbacks and rewards

The migration to partial online pedagogy entailed many challenges and setbacks but also brought some rewards. As mentioned before, TPL is a course unit in the Biomedical Engineering course at the University of Minho. This course unit is exclusively laboratorial, which in itself made the transition to blended learning here proposed even more challenging and which ended up being applied during the pandemic situation experienced recently.

This transformation endeavour was a tough and time-consuming task, requiring great flexibility and availability of the teaching staff and therefore a great and well-coordinated teamwork. The videos had to be prepared in advance to be timely provided to the students in order to give them the possibility to clarify any doubt in the synchronous classes scheduled for this purpose. Moreover, these videos aimed to familiarize and prepare students for the work to be carried out in the lab environment. Since each student only attended two in-lab classes due to the pandemic constraints and, therefore, operated two of the five proposed works, these videos acquired special importance since they allowed students had a closer and informative view about the installations and operating modes of the laboratory works not carried out by themselves. These videos and all the TPL supporting documents were published on the e-learning platform Blackboard, a digital space aimed at the University of Minho's students, providing them with access to the contents of their course units. It must be also stressed that students were also notified by email whenever any information or class support document is posted.

One of the hurdles of this reformulation was the high number of students enrolled in the course unit (seventy-three), which reduced the possibility of a more active and personal learning and teaching dynamics. The class size and the safety rules imposed by the Covid-19 pandemic also impaired students’ attendance to all the face-to-face classes (in the rotating system) and consequently the continuous contact with the laboratory facility and the laboratorial modules of all the works programmed in TPL. Although it was mandatory for the entire group to elaborate the mini-report regardless of the student who performed the work in the laboratory, it was difficult to scrutinize whether the mini-repots resulted from teamwork, involving the participation of all the elements, in a cooperative effort, or individually work. However, this is a doubt that occurs in any work performed in group and not directly related to the fact that only two students in the group have attended each practical class. Even so, it is credible to assume that, for most groups, intra-group work management has been done according to the practical work performed. This meant that the two students that carried out the practical work were the ones designated by the whole group to elaborate the correspondent mini-report. This setback could have been partially solved through intragroup evaluation, aspect not taken into consideration when preparing the evaluation methodology for this course. However, to be reliable, students would have to make it seriously and conscientiously. The number of students in each shift also made difficult to reliably define the individual evaluation of each student since the majority of the evaluation components were accomplished in group. The most trustworthy individual assessment components were obtained in face-face classes such as the final written evaluation test and the teachers' appreciation on the participation, interest and performance of the work done by the students in the in-lab classes. This last aspect was facilitated by the small number of students present in each in-lab class. Although not foreseen, as it was dictated by the pandemia crisis, the reduced number of students in each in-lab class also allowed for a closer and, therefore, more profitable and constructive interaction between students and teachers. This close teacher-student relationship also increased the assumption of responsibility of each student in carrying out the work since, at that moment in the class, he was fully responsible for the good laboratory performance and the experimental data his group would obtain. These findings emphasised the importance of the balanced number of students in each class for the success of teaching-learning strategies.

Another setback of this mode of learning is related with the quizzes launched along the semester. These quizzes were created aiming to allow teachers and students to make a diagnosis of the previous and acquired knowledge by students. However, as they were on-line carried out, it was very easy for students to share answers knowing there’s nobody is watching and, thus, biased the final scores.

Despite the challenges and setbacks previously mentioned, this blended teaching/learning practice also had some rewards. The positive feedback acknowledged by students and the good marks attained by them, as well as the fulfilment of the TPL program and the achievement of the proposed objectives were some of them. From the teachers’ point of view, this transformation effort in engineering education allowed teaching staff to apply and thus learn more about blended learning practice. This knowledge and acquired experience will for sure assist teachers in new challenges of transformation of other curricular units the teacher staff will embrace for.

4 Study design and data collection

Regarding students, a survey, filled at the end of the module of TPL, was the method used to explore, gather, process and evaluate the student's opinions about the reformulation of this module of the TPL classes. This survey was a valuable source of feedbacks for teachers and self-reflection for students and will support the planning of future classes and improve the teaching and learning methods. Students were asked to complete a questionnaire whose questions are presented in Table 1. Of the seventy-three students enrolled in this course unit, thirty-five responded to the proposed survey, corresponding to approximately 50% of the students. Students' participation was voluntary and anonymous.

Table 1- Survey questions asked to students at the end of the module.

Survey questions
1- In general, in this contingency situation, how do you evaluate the organization of TPL classes?
2- The previous availability of the teaching materials (videos, manuals and protocols) was relevant and useful for the programming of group work?
3- From the pedagogical materials available (videos, protocols, course unit manual), which one (s) was (were) the most relevant and useful for the preparation and programming of the works and understanding of the objectives of the experimental activities?
4- The feedback that the teachers communicated in each class regarding the work done in the previous class was useful and relevant for the following works?
5- Did the elaboration of the mini-reports contribute to the understanding of the theoretical foundations underlying each work and to the achievement of the learning objectives?
6- Indicate suggestions for improving the functioning and teaching / learning of this course unit.
7- Indicate the least successful aspects in the functioning of this course unit.
8- Give general feedback on LFTM.

5 Results and Discussion

The responses to the questionnaire were on a five-point rating scale from (1) through (5). In the first question 1 corresponds to "bad" and 5 to "excellent", and in the other questions 1 corresponds to "No" and 5 to "Fundamental".

Considering question 1, none of the students considered that the classes were poorly organized and most students think that the classes were well organized, with around 17% even considering the organization of the classes excellent.

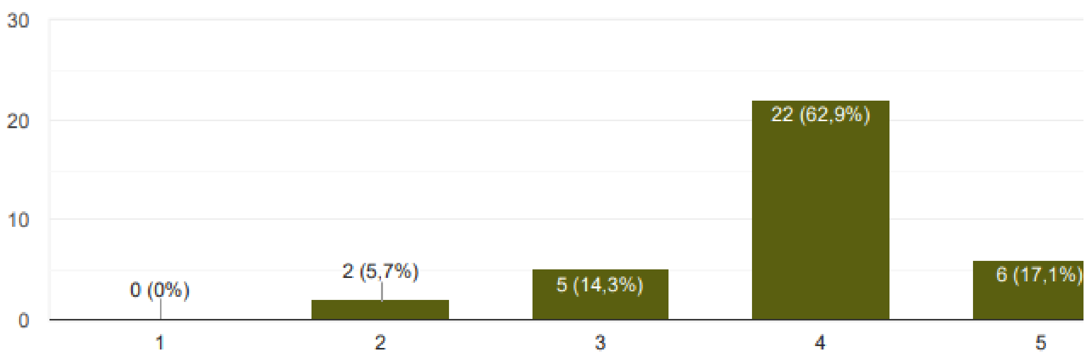

Figure 1 – Student's responses to the question evaluating the organization of the classes.

When asked about the offer and the usefulness of the previous availability of the pedagogical materials (videos, manuals and protocols) for the programming and management of the group work (Question 2), only two students considered that the availability of the supporting material was not relevant and useful for the organization of the teamwork. On the other hand, 60% of the responding students considered as fundamental the provided pedagogical materials (Figure 2).

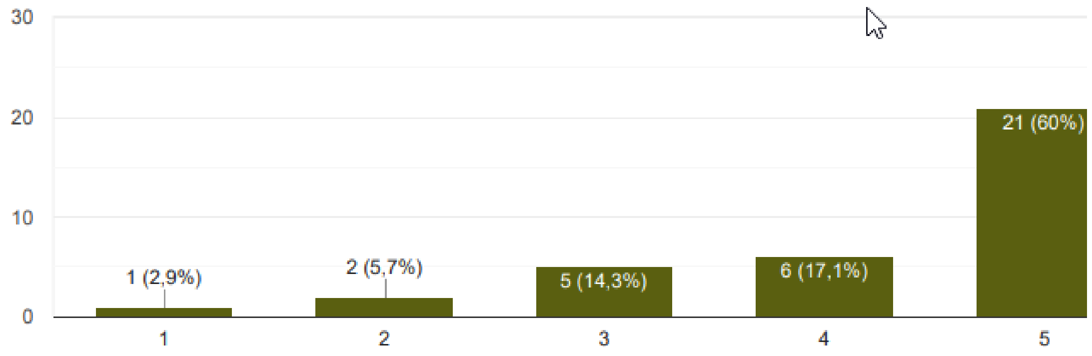

Figure 2 – Student's responses to the question evaluating the utility of the availability of teaching material (videos, manuals and protocols) for the programming of group work.

More than 50% of the students who answered the third question mentioned that both protocols and videos were the most relevant and useful materials to the preparation, programming and understanding of the laboratory modules proposed in TPL. About 25% of answers were attributed to protocols or to videos individually.

Regarding the question about whether the feedback that the teachers communicated in each class regarding the work done in the previous in-lab class was useful and relevant for the following works (question 4), only two students considered as non-fundamental. About 47% of the respondent students recognized teachers' feedback on mini-reports extremely important and crucial for the following works (Figure 3).

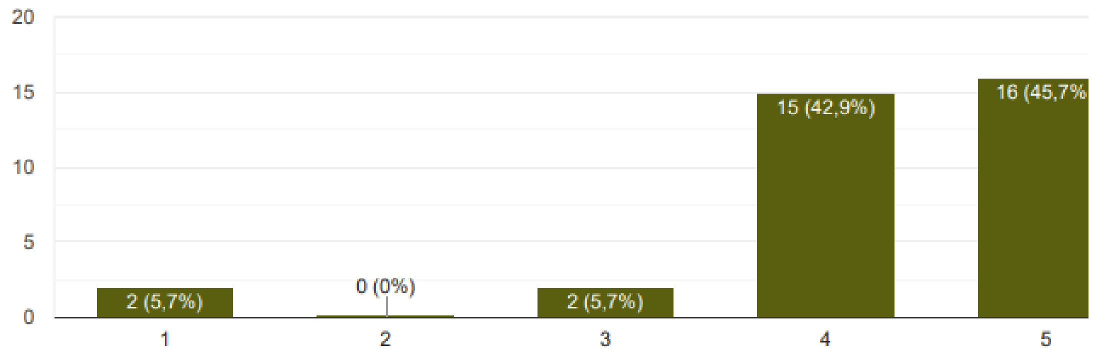

Figure 3 - Student's responses to the question evaluating the feedback given by the teachers about the previous work.

To question 5, "Did the elaboration of the mini-reports contribute to the understanding of the theoretical fundamentals underlying each work and to the achievement of the learning objectives", all students considered the elaboration of the mini-reports relevant to TPL classes/works comprehension and to consolidate previous knowledge and to, consequently, attain the learning objectives, of which 31.4% answered 5 (extremely fundamental) (Figure 4).

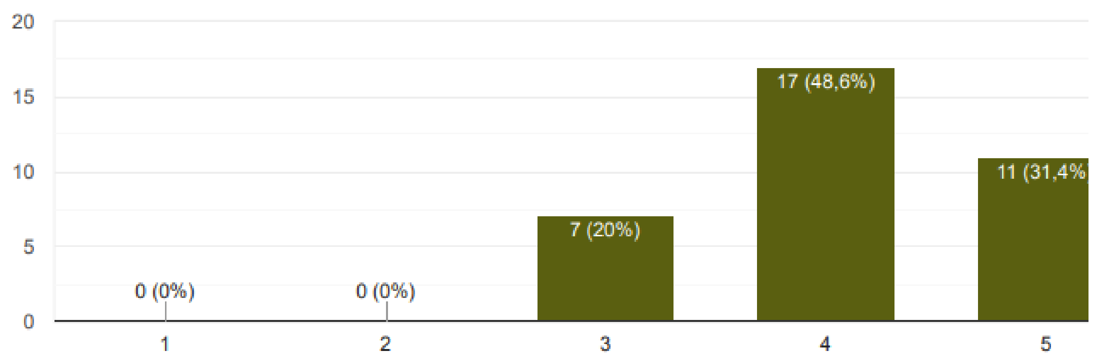

Figure 4 - Student's responses to the question evaluating the utility of the elaboration of mini-reports.

For improving the functioning and teaching/learning practices of this course unit, several relevant suggestions were given by the students, namely: intragroup evaluation; the communication of grades along the semester and not just at the end for students to be aware of their evolution throughout the course; more lab shifts (if possible) and launching quizzes before each laboratorial activity. These suggestions seem to be a sign of students' growing willingness to be involved in the TPL learning outcomes.

Regarding the less well achieved aspects in the functioning of this laboratory course unit, fourteen students gave their personal opinion. The mainly observations are related with the non-communication of quantitative grades during the performance of the different evaluation components, reinforcing the need of intragroup evaluation. They also pointed the various sections of the mini-reports as too extensive, and, in their opinion, the final written evaluation was needless.

In turn, thirteen students expressed their general feedback on TPL classes highlighting the following positive aspects: the availability of the teaching staff; the good organization and support of the laboratorial activities, the stimulus for the discussion and practical analysis of the contents of the theoretical classes (heat and mass transfer phenomena) underlying this course unit, being reported as an excellent complement to this; and the constant development of knowledge throughout the progress of the lab works included in this course unit. Aligned to the least successful aspects previously mentioned, as negative feedback, students highlight the excessive work involved in this course unit and, once again, the non-need of the written test; the need for more face-to-face in-lab classes, although they aware that this event was due to the restrictions inherent to the current pandemic situation. In general, the respondents considered that TPL classes "went well".

6 Conclusion

The TPL pre-programmed reformulation and coincidentally the challenging time resulting from the covid-19 pandemic obliged to a sudden transition, partial or total, to online pedagogy education and to a different teaching and learning dynamics. This task, although hard and time consuming, inherent to any course transformation and more challenging and exhaustive due to the Covid-19 situation, was considered successful. Despite the challenges and setbacks, inherent to the program and objectives of a laboratory course in engineering, the goal of transformation of TPL has been fulfilled and, in general, the students involved in this new blended learning practice acknowledge as very positive this endeavour.

Suggestions and recommendations are mentioned in this paper aiming at a broader applicability in related course units and demonstrating the effectiveness and success of the blended learning tools in the complement of the traditional face-to-face learning. In addition, teachers felt that this transformation endeavour provided them with knowledge, experience and new learning skills that will help, not only to consolidate the TPL transformation, refining the less well achieved aspects, but also to have the willingness to expand and strengthen those competences in the transformation of other curricular units.

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Science Communication in Bioengineering and Biotechnology: active and collaborative learning project

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Abstract

In a society increasingly dependent on science and technology, the need to equip our students with the most varied digital and communication skills is crucial. Active and collaborative learning among peers is essential for the acquisition of transversal skills. Communication is one of the main tools that the Engineer uses to reach his target audience. "Science Communication in Bioengineering and Biotechnology" (CCBioTec) is a project on Innovation and Development of Teaching and Learning supported by Center IDEA-UMinho, a structure that emerges to promote and value Innovation and Development of Teaching and Learning at the University of Minho. CCBioTec is transversal to a set of Learning Units (LU) under the responsibility of the Department of Biological Engineering (DEB), including one LU of each year of the Integrated Masters in Biological Engineering and in Biomedical Engineering. The main goals of CCBioTEc are: to foster the awareness of the DEB educational community on the importance of science communication, as well as to develop science communication skills, through the production of short videos (pitches) displaying the explanation, in a simple and dynamic way, of complex concepts of Bioengineering and Biotechnology related with the curricula of each LU. CCBioTec started in the second semester of 2020/21, and it will go on in the 1st semester of 2021/22. The project was designed to be implemented according to the following steps: 1 - Technical and pedagogical training of teachers; 2 - Technical training of students involved in the project - Week CCBioTEC-2021; 3 - Development of materials for "Science Communication in Bioengineering and Biotechnology"; 4 - "CCBioTec-2021" competition. In CCBioTec, teachers presenting himself as a mediator/facilitator of learning, boosting students' development of transversal skills, collaborative work, decision making and the expression of ideas, together with the acquisition of knowledge foreseen in the curricular contents of the LU.

Keywords: Science Communication; Active Learning; Bioengineering; Biotechnology.

1 Introduction

Communication is the main tool through which an Engineer conquers his target audience, which can vary from the management bodies of a company or the general society to the promotion of a product or a service. Communication is thus used to attract the attention of the interlocutor and is the key to transmit clean, clear and concise information (Kirkman and Turk, 2002).

The digital age has completely changed the communication paradigm. If a few years ago we used only PowerPoint to show results or present our work, today the general public, including the student, is more demanding, and thus more difficult to capture/involve (Kahu, 2013). So, social networks have become privileged vehicles for transmitting fundamental information, using short videos, animations and graphic images (Kolbitsch and Maurer, 2006). If, on the one hand, these advances are good for the globalization of information, on the other hand they can bring serious obstacles to those who are not prepared for this new way of communicating.

New tools appear essential to use, to teach and to motivate, namely tools for sharing documents (ex. Padlets), elaboration of animations (e.g. Animaker), infographics (e.g. Piktochart) and editing videos (e.g. Shotcut). Consequently, these are new skills that teachers and students need to acquire and/or reinforce (Lima et al., 2017).

The current pandemic conjecture has also led to the need for a very rapid adaptation of traditional and face-to-face teaching to the online model and more recently to the hybrid model, where attracting the attention of students, was and is a constant challenge to teachers (Watermeyer et al., 2020). In addition, the Society's interest in basic science concepts, namely Bioengineering and Biotechnology, also increased. Therefore, science communication emerges as a transversal competence that the Department of Biological Engineering would like to prioritize in the training of its students, contributing to their professional success in the future, as well as enabling them to become more active in society.

The teaching community of DEB has made a great effort to promote innovation in the education of quality it offers to its students. A large number of DEB teachers have participated in trainings offered by Centro-IDEA, a structure that emerges to promote and value Innovation and Development of Teaching and Learning at the University of Minho. DEB teachers are already involved in Communities of Pedagogical Practice. DEB regularly promoted "Pedagogical Innovation Workshops" for its teaching community.

The purpose of this paper is to show how DEB intends to improve the development of Scientific Communication skills in your students, through the project "Science Communication in Bioengineering and Biotechnology" (CCBioTec), that is a DEB project on Innovation and Development of Teaching and Learning supported by Center IDEA-UMinho.

The main goals of CCBioTEc are: to foster the awareness of the DEB educational community on the importance of science communication, as well as to develop science communication skills, through the production of short videos (pitches) displaying the explanation, in a simple and dynamic way, of complex concepts of Bioengineering and Biotechnology related with the curricula of each LU.

At the same time, the intention is to introduce changes in conventional pedagogical practices, namely in terms of content and competence assessment, which is intended to be more diversified and phased, emphasizing the importance of feedback by peers and teachers (Lima et al., 2007). Finally, the ambition is to leverage the creation of a Pedagogical Innovation Community in the area of Engineering, which is intended to be transversal to other areas, in addition to Biological and Biomedical Engineering, while promoting research on the value of new applied pedagogical practices.

2 Implementation process

The Project "Communicate Science in Bioengineering and Biotechnology" (CCBioTec), is transversal to a set of Learning Units under the responsibility of the Department of Biological Engineering (DEB), including at least one LU each year of the Integrated Masters in Biological Engineering (IMBiolE) and Biomedical Engineering (IMBiomE). The selected LU (theoretical, theoretical-practical or laboratory) have in common learning objectives that imply the acquisition of engineering concepts, as well as the understanding of Chemical and Biological Processes.

Thus, the present Project intends to foster, in the educational community of DEB, the awareness of the importance of science communication, in a society increasingly dependent on science and technology, and arises from the need to equip our students with the most varied digital and communicational skills, while promoting active and collaborative learning among peers. CCBioTEc also intends to promote the interaction, involvement, participation and collaboration of students, in the development of contents, through the elaboration of short videos - pitches with the explanation, in a simple and dynamic way, of complex concepts of Bioengineering and Biotechnology, concepts related to the learning objectives of the LU involved in the project, also contributing to the improvement and quality of learning.

Within the scope of the Project CCBioTec, it is intended to develop transversal skills that will improve future professional performance of Biological and Biomedical Engineering students, including socio-emotional and behavioural skills, such as assertiveness, team work, planning, time management, initiative, as well as communication skills, such as clarity, oral fluency, objectivity, non-verbal communication, empathy, conviction, among others (Lima et al., 2017).

Simultaneously, it is intended to create an active learning scenario that leads students to understand, in an integrated and contextualized way, complex engineering concepts, predicted as learning outcomes of the various LU involved, contributing to the educational success of students and to the creation of a legacy of resources that can be voluntarily made available.

The project implementation started in the 2nd half of 2020/21 and it will continue in the 1st semester of 2021/22. In the first stage of implementation, as stated above, only one LU for each year of the both Courses was covered (Table 1). However, it is intended to replicate in other LU of the same courses and in other study cycles, thus contributing, to increase the development of transversal skills in our educational community.

Table 1. Courses units per year of the Integrated Masters in Biological Engineering and Biomedical Engineering.

Course/Year	1st	2nd	3rd	4th
IMBiolE	Introduction to Process Engineering	Transfer Phenomena II	Bioprocess Laboratories	Process Control and Instrumentation
IMBiomE	Introduction to Biomedical Engineering	Heat and Mass Transfer	Clinical Support Services	Treatment of Hospital Waste and Effluents

The project has several steps, implemented in different stages, and that are going to be described below.

2.1 Technical and pedagogical training of teachers involved in the project

To achieve the proposed objectives, the project started with a technical-pedagogical training of teachers, to allow the insertion, in the teaching practice, of competences in digital literacy. This training, was entitled "hands-on digital tools", and took place on March 17th, with 51 participants including career teachers and researchers who collaborate in the teaching activity of DEB. This training, complementing the one that Centro-IDEA has already promoted to University of Minho teachers. During this training, the teaching team had the opportunity to explore the pedagogical potential of the different technological tools (e.g. for creating mind maps, animated videos and online questionnaires).

2.2 Technical training of students involved in the project - Week CCBioTEC-2021

In order to promote the technical training of the students involved in the project, an initiative entitled "CCBioTEC-2021 Week" was organized. Around 300 students signed up for the actions promoted, which took place between April 12th and 16th, using digital platforms, and which included Lectures and Workshops on Science Communication, as well as the presentation of Success Cases in Science Communication.

During "CCBioTEC-2021 Week" specialists in Science Communication, either from the University of Minho (Institute of Social Sciences), and other Higher Education institutions were invited as speakers, thus fostering inter- and intra-institutional collaboration. Three 60-minute lectures occurred on consecutive days at 6 PM (after classes), which include themes as: "Science Communication for an Audience", "Help, I have to speak in public. What now?" and "Science Communication Success Cases". The other two days, were dedicated to Workshops that intend to teach the participants to use some digital tools, software and/or techniques useful in Science Communication. Oral communications and workshops were open to the entire DEB community, with online transmission with streaming on YouTube, and it had an average daily participation of 110 participants.

2.3 Development of materials for "Science Communication in Bioengineering and Biotechnology"

Active and collaborative learning were promoted, where communication materials for scientific concepts of Bioengineering and Biotechnology were developed, comprised in the learning objectives of the different CU. The concepts selected by the students were adapted to the pedagogical context of the specific CU and validated by the respective teachers. The final aim was to create a one-minute pitch, using a video / graphic animation, which were made available voluntarily to the entire DEB educational community, through the institutional website.

In a pedagogical project like this, based on the principles of active and collaborative learning, in which students are at the centre of the process, the skills of research, selection and structuring of information were reinforced by the teaching team. It is also important to emphasize that the use of technological tools for the production of communications of scientific concepts guided the students' activity towards the final objective, the apprehension/appropriation of certain scientific concepts of Engineering and Biotechnology, as well as, aroused curiosity and the interest of colleagues in similar concepts, through the creative and effective creation of content that was integrated in the final product - pitch.

The video editing and/or create animations software were chosen by the students according to their relevance and applicability, but they were encouraged to use licenses free of charge. Regardless of the methodological adaptations implemented by each teacher, it was important to carefully guide each group of students through the content design process so that the curriculum content was not lost sight of.

2.4 CCBioTec – 2021 competition

At the end of the second semester (June), it is foreseen to organize a Science Communication in Bioengineering and Biotechnology competition, which was already announced in the week CCBioTEC-2021, on the Department's institutional page and on social networks. The aim of this contest is to give visibility to the pedagogical practice developed, share experiences and naturally motivate other teaching colleagues to implement these methodologies in their LU. Students were encouraged to compete with the materials produced in the LU, with the attribution of symbolic prizes per year for each course and the selection of 3 grand prizes.

The general rules of the contest were:

- Each video will have to expose in a simple way, a concept of Bioengineering and or Biotechnology, preferably answering a key question;
- The length of the video is a maximum of 60 seconds;
- The video can contain animations, characters or actors;
- The images used in the videos must be from the authors or from a non-copyrighted image bank;
- Only 2 pitches per LU, that integrate the CCBioTec project, were considered for the competition (a selection of which will be at the expense of the teacher responsible for the LU);
- Students/groups of students from the 2nd and 3rd cycles under the responsibility of Centre of Biological Engineering (CEB) were also eligible to the competition, and must comply with the first 4 clauses;
- The remaining videos of each course will be made available voluntarily on a link already placed in the CCBioTEc padlet and will integrate a future platform with the various videos produced;
- The Jury's vote is worth 70%, the public vote is worth 30%;
- Public voting (likes on Facebook and Instagram platforms) period will last one week.

The team of juries is composed by several teachers involved in the project, by the DEB/CEB direction and by invited experts.

3 Learning Assessment and project monitoring

The teachers of each LU are responsible for the identification of the topics/concepts of Bioengineering and Biotechnology contemplated in the learning objectives of each LU, as well as for the delivery dates of the respective digital content – pitches - produced by each group of students, and for the assessments.

The assessment of the quality of the content produced by the students, will be based on assessment grids built by the team of teachers included in the project and will be transversal to all LU (table 2). The evaluation/feedback of the peers, expressed during the presentation/availability to the class will also be empathized. This exercise will be an integral part of the LU assessment component, corresponding to 10% to 20% of the final classification.

Table 2. CCBioTec Assessment Grid

	Contents						Narrative						Inovation				Global Assessment				**Grade**
	Relationship with the theme (Subject focused, ability to synthesize)			Approach to the theme (Ideas organization and interrelation, information clarity, particularities)			Acoustic and audio-perceptual evaluation (Voice tone, speech speed, diction, fluency, musical background)			Graphic Interface (Animation, video editing, filming)			Resources (Attractiveness, impact, dynamics)				Message effectiveness for Science Communication				**0 to 20**
	Poor relationship	Average relationship	Good relationship	Inadequate approach	Reasonable approach	Good approach	Not suitable	Suitable	Very Suitable	Not suitable	Suitable	Very Suitable	Without innovation	Few differentiating elements	Various differentiating elements	Very innovative	Ineffective	Effective	Very effective	Excelent	
	1	2	3	1	2	3	0,5	1	2	0,5	1	2	1	2	3	4	1	2	4	6	
Team			x			x			x			x				x				x	20

At the end of the semester, a new survey was made to the students involved to validate whether they have acquired transversal skills and whether initial perceptions regarding Science communication have changed.

Monitoring the success of the project will be decisive in deciding on its extension to the 1st semester of 2021/2022. It is also expected in this second period of implementation the involvement of LU teachers initially selected in the team of trainers, as well as some groups of students to share their experiences and showcase their pitches.

4 Preliminary results

Prior to the technical and pedagogical training of teachers, they were asked about their willingness to be part of the CCBioTEC project, and 29.8% answered affirmatively, which included 17% that were already part of it, but 53.2% did not express interest. These results reveal that there are still teachers in DEB community who need to be motivated for pedagogical themes, however it is not a discouraging result.

Before the students training week, a survey was sent to all enrolled students (only 152 students responded), which aimed to assess the students' initial knowledge of Science Communication. Initially, we asked students if they knew what Science Communication is, and 59.9% answered that they have a vague idea and only 16.4% revealed to know perfectly what Science Communication is. It should be noticed that although 23.7% said that they do not know what Science Communication is, they demonstrated an interest in knowing it. The vast majority, 94,1%, emphasized that Science Communication is important for society in general, however a small number of respondents said it is only important for researchers (2%) and 3,9% said it is important for the student audience. When we questioned how Science Communication is mostly done, 91,3% answered that it was through the publication of scientific papers, however other forms of Science Communication were also evidenced, namely the elaboration of didactic videos about scientific concepts (76%). Questioned about how they feel if they have to make a science communication, 45.7% said that they do not know how to plan a communication and 45.7% also reported that they did not know what they have to transmit. As expected, 23% referred to an uncomfortable feeling when communicating science and they would only do it if they were forced to. Asked how they feel if they have to make an oral presentation, 69.7% said they were very anxious, 42.8% feel uncomfortable, 17.8% motivated and only 5.9% very confident. So, these results highlighted the importance of this project in DEB student's community.

In this first survey we also asked the respondents to describe Science Communication in three words (Figure 1). The majority replied that it should be clear, captivating, simple, dynamic and objective, however they also highlighted the importance of the content, that need to be correct, accurate and adapted to the audience.

Figure 1. Science communication in three words by the students in the beginning of the project

At the end of the semester, a new survey was made to the students involved to validate whether they have acquired transversal skills and whether initial perceptions regarding Science communication have changed. We asked students if they knew what Science Communication is, and 43,1% answered that they have a vague idea but 54,9% revealed to know perfectly what Science Communication is, which is a big difference when compared to the initial survey. The vast majority, 97%, continue to emphasized that Science Communication is important for society in general, however a small number of respondents said it is only important for researchers (1%) and 2% said it is important for the student audience. When we questioned how Science Communication is mostly done, 96% answered again that it was through the publication of scientific papers, however other forms of Science Communication were equally evident, namely the elaboration of didactic videos about scientific concepts (90%).

Questioned about the CCBioTec training week, 9,8% said that it exceeded the expectations, 56.9% reported that the training met expectations, but 23,5% were disappointed. Regarding the schedule of the sessions, most participants considered it adequate. Similar positive opinion was stated about the use of a padlet to organize and display all the information related to the CCBiotec project, as 72.6 % of the participants considered thos tool useful and/or very useful.

5 Conclusion

In conclusion, this project essentially aimed at a redefinition of the role of the teacher who presents himself as a mediator/facilitator of learning, promoting in students the development of transversal skills, collaborative work, decision making and the expression of ideas. Simultaneously it intends to facilitate the acquisition of knowledge foreseen in the curricular content of the LU that were included in the project. The CCBioTec project is being a challenge for both students and teachers. The challenge of accurately and effectively built and present for a diverse audience the mean of engineering concepts in shorts videos stimulated and speed up the development of synthesis capacity skills, as well as of thinking methods and the problem-solving capability of students. This endeavour of creating videos to communicate science, although hard and time consuming, was considered successful. This believe was grounded on the positive students' opinion as most of them recognized that this project helped them to develop communication skills. Furthermore, students' willingness of, in the next semester, preferring to make videos instead of other forms of communication in science is also an evidence of the CCBioTec project's pedagogical value.

For the success of this initiative, the previous technical training of students and teachers involved in the project in the scope of previous CCBioTec week was fundamental as the launching ramp. As the number of the effective participants was lower than the expected, in the next semester a wider dissemination effort of this training week will be made, exploring the social networks that are, at the moment, essential, to reach the student audience. In addition, it is also intentioned to improve the program of the 2nd edition of the CCBiotec week, refining the less well achieved aspects, to meet the suggestions disclosed by the participants in the intermediate survey, namely increase the time to explore and acquire experience into the software to create videos and graphical animations.

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Learning science during summer vacations and its effects on attitude and anxiety towards research

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Abstract

The outbreak of COVID-19 had a great impact on education with the sudden shift from traditional to online learning. As a result, the difficulties experienced by students increased, professors had to adapt the teaching method of the contents and experimental activities were all transmitted from a screen, making this a difficult task for everyone. In this context, the resumption of in-person activities is of great importance to surpass the difficulties that this pandemic crisis has brought to students learning. Motivated by this necessity, the Foundation for Science and Technology (FCT), proposed a program called "Summer with Science". This program aimed to develop presential activities with the participation of students, professors, and researchers in the summer of 2020, that involved innovative solutions related to the COVID-19 pandemic. i9Masks was one of the interesting projects that emerged from this initiative and it consisted of developing transparent facial masks for preventing the virus' dissemination. This project joined students of different engineering and biological sciences at any level in a Higher Education Institution to learn science. In order to understand the impact of this course on student's motivation to conduct research, in the present study, a questionnaire was used to collect the data from the students who participated in the i9Masks summer project. The same questionnaire was applied to non-participants as a control group. After the data are gathered, the results were evaluated, and it was observed that effectively this course had a great and positive impact on student's perspective on research activities. Significant differences were observed regarding the attitudes towards research between participants and non-participants.

Keywords: Attitudes Towards Research, Engineering Education, Experimental Learning, Summer Project.

1 Introduction

The global pandemic of COVID-19 forced us to stay at home for several months and this confinement had an enormous impact on society. The closure of educational institutions and the rapid transition to digital education seriously affected students' learning and motivation, and psychological problems emerged, including frustration, stress, and depression, making this an overwhelming issue (Bestiantono et al., 2020; Chaturvedi et al., 2021; Khan et al., 2020). For this reason, the implementation of measures to improve the learning experience and overpass the difficulties that this pandemic crisis has brought to students' performance, is essential. One great initiative that contributed to this was proposed by the Foundation for Science and Technology (FCT), through a program called "Summer with Science". This consisted of on-site activities performed by students, professors, and researchers, both in Polytechnics and Universities in the summer of 2020, that involved innovative solutions in response to the COVID-19 pandemic.

After a long confinement, students had the opportunity to carry out in-person research activities with a grant from FCT and to have a closer involvement with the ongoing COVID-19 investigation, which piqued their curiosity. Among the interesting projects that arose, the project entitled i9Masks was fascinating. This project aimed to develop transparent facial masks for preventing the virus' spreading and it allowed students of different engineering and biological sciences at any level in a Higher Education Institution to learn science in an active and practical way, a difficult task to perform. Teaching science remains complex and challenging, and it has been stated that through engagement in scientific investigation, students' learning experience and skills/competencies are honed and they open up wide perspectives and develop better team spirit (Ballesteros et al., 2020; Gunel, 2006; Lemberger et al., 2011; Moeed, 2013; Premalatha, 2019). Nevertheless, the importance of carrying out research activities during a higher education course has not been an active field of investigation in recent decades, existing few studies addressing this topic (McAndrew et al., 2011; Nascimento et al., 2013; Pinto et al., 2014; Saliba et al., 2019). For instance in Brazil, there is an undergraduate research program that aims to stimulate and encourage dentistry students to participate in research projects (Saliba et al., 2019). According to a study conducted by Saliba and co-workers (Saliba et al., 2019), students with scientific initiation published more papers than those without this practice, proving that this plays an important role in enhancing the experience of students in the development of scientific works. In another interesting study, also about dentistry students (de Araújo et al., 2016), was verified that scientific initiation scholarships seem to encourage undergraduate students to pursue an academic post-graduation program. In another investigation (Fava-de-Moraes & Fava, 2000), it was also stated that students involved in scientific initiation develop distinguished skills and presented better results, and need less time for finishing their thesis.

In general, the previous studies showed that the involvement of undergraduate students in research activities allows them to have a better performance in conducting research activities, namely in developing scientific papers. However, these studies focused mainly on dental education programs and on the scientific production of students.

At Portugal, many engineering students are unaware of the existence of the research as a career field until they enter university. Even then, the research experience is often introduced late in course' curriculum, in many cases only during the final dissertation, which can influence the attitude, i.e., the positive or negative feeling about doing research and the anxiety, as a fear or a concern how to do the research process. Papanastasiou (Papanastasiou, 2005) developed the "Attitudes Toward Research" scale (ATR) to explore this multidimensional factor structure based on the perception that undergraduate students usually tend to see research course methods with negative attitudes, and to feel anxiety, characterized by tension, stress, fear, and difficulties in understanding research.

In this regard, the present study aims to explore the students' attitude and anxiety in conducting research and to evaluate the effect of participating into i9MASKS course, taking into consideration the ATR scale presented by Papanastasiou (2005). To this end, a questionnaire was developed and implemented with students who participated in the i9Masks summer project and also from non-participants (control group).

2 The I9MASKS

The I9MASKS project intended to use state-of-the-art technologies for the development of polydimethylsiloxane (PDMS) facial masks, with characteristics such as transparency, lightness; breathability; flexibility; reuse; recycling, and efficiency in protecting COVID-19. In order to help the project implementation, a non-accredited course was designed. Aimed at engineering students enrolled at any level in a Portuguese Institution of Higher Education, the i9Masks summer course was developed to take place during the summer vacation of 2020, during a 3 months period between July and October, in two campi of the University of Minho (Campus of Azurém in the city of Guimarães and Campus of Gualtar in the city of Braga) during daytime and in an intensive and face-to-face regime. The application for the course was made through an online application, and the selection of candidates was made by curriculum analysis, namely academic merit and scientific experience in the area of the course. Twenty-one internship students were selected, of which:

- 13 female students and 8 male students;
- 10 students from the University of Minho and 3 from other higher education institutions in the North of Portugal;
- 14 undergraduate students, 6 master student, and 1 PhD student;
- 6 Mechanical Engineering students, 5 Electronic Engineering students, 3 Biomedical Engineering students, 2 Materials Engineering students, 2 Industrial Engineering students and, 3 students from other engineering courses/ areas.

During the summer course, each student was accompanied and supervised by a doctoral researcher and he was involved in laboratory work in a "learn by doing" methodology. The students attended a set of workshops (?) organized according to four modules: 1) Seminars in Science of Engineering, 2) Introduction to Research in Engineering Sciences, 3) Fabrication and Tests of Polydimethylsiloxane (PDMS) Masks and 4) Numerical

Simulations. Given the multidisciplinary characteristics of the project, the course involved around 17 professors and researchers from 3 research centers at the University of Minho ((MEtRICs, ALGORITMI, and CMEMS) and 5 monitors.

The students worked as a team in different laboratories for a total of twelve experimental and numerical projects implemented. At the end of the summer course, all students involved participated in workshops to present and discuss the prototypes and projects developed at I9MASKS. The feedback received from those involved in I9MASKS (teachers, researchers, monitors, and students) was very positive, with everyone recognizing the unique teaching-learning experience associated with this summer course and its potential to encourage students to become actively involved in practical engineering projects.

3 Methodology

The research questions that were examined are the following:

(1) What are the attitudes and anxiety towards research experienced by engineering students who were enrolled in the I9MASKS summer course class?
(2) How does this summer course participation affect students' attitude and anxiety towards research?

To assess attitudes and anxiety, a self-administered questionnaire was developed considering three groups of questions. The first group included questions to characterize the respondent, such as age, gender, course, past and present research experience. The second group considered the attitude and anxiety questions towards research. Finally, in the third group, the questionnaire included opinions and behavior questions regarding the course.

After performing a pre-test, the questionnaire was considered validated and made available to respondents through Google Forms. In the follow-up, an invitation was sent by email to the participants who had completed the summer course at the University of Minho to answer the questionnaire and to invite three or four colleagues who did not participate in the summer course ("fill the questionnaire and send the link to other colleagues to answer"), thus resulting on a snowball sampling technique.

These non-participants engineering students were considered as a control group, i.e, group in an experiment that, does not receive the intervention (Saunders et al., 2009). This control group will be used as a baseline to compare with the students who participated in I9MASKS and then evaluate the effect of the course.

A total of 47 responses were received. The age group of the respondents ranged from 20 to 33 years (mean equal to 22.06 years) and the significant majority of respondents do not have published articles. Demographic variables are presented in Table 1.

Table 1. Demographic characteristics of students (n=47)

	Subgroup	Frequency	Percentage
Type	Participant	18	38,3
	Non-participant	29	61,7
Gender	Female	29	61,7
	Male	18	38,3
Qualification Level	Undergraduate	16	34,0
	Bachelor´s degree	23	48,9
	Master's degree	8	17
Number of published research papers	0	45	95,7
	1	1	2,1
	2	1	2,1

4 Results and Discussion

The paper explores results for attitudes and anxiety towards the investigation. The questions were based on the Attitudes Toward Research (ATR) scale (Papanastasiou, 2005) with 32 items on a five-point Likert scale ranging from "1" (strongly disagree) to "5" (strongly agree). The items in the ATR can be subdivided into five subscales (Table 2).

Table 2. ATR subscales

Scale	Subscale	# items
Attitudes Toward Research (ATR) scale (Papanastasiou 2005)	Research usefulness for career	9
	Research Anxiety	8 (7)
	Positive attitudes toward research	8
	Relevance to life	4
	Research difficulty	3

The analysis is made question by question in order to obtain a more detailed evaluation of the results and, thus, to explore the differences between the two groups of respondent:

(1) the participant's group, i.e., respondents who completed the I9MASKS summer course and,
(2) the control group with non-participants of I9MASKS

After assessing the normality of the data with Kolmogorov-Smirnov tests, it was found that the responses of the two groups do not follow a normal distribution. Thus, Mann-Whitney non-parametric tests will be used to compare the mean of the responses between the group of I9MASKS participants and the control group (non-participants).

4.1 Research usefulness for career

Table 2 shows the data obtained regarding the research usefulness for career questions. The participant group has higher mean values, which indicate a perception of superior usefulness for career (Table 3). The Mann-Whitney tests indicate that there are significant differences in students' perception of the usefulness of research between participants and non-participants in questions 7.7 – "I will employ research approaches in my profession" ($p = 0.015 < \alpha = 0.05$) and 7.8 – "The skills I have acquired in research will be helpful to me in the future" ($p = 0.013 < \alpha = 0.05$). These results indicate that I9MASKS participants consider research an important tool for their future professional activities, suggesting the existence of a positive contribution of this course on students' attitudes towards research.

Table 3. Research usefulness for career results.

Research usefulness for career statements	Mean		Mann-Whitney p value
	I9MASKS Participant	Non-Participant	
Q 7.1: Research is useful for my career	4.44	4.21	0.550
Q 7.2: Research is connected to my field of study	4.44	4.10	0.357
Q 7.3: Research should be indispensable in my professional training	4.33	3.90	0.310
Q 7.4: Research should be taught to all students	4.22	4.00	0.457
Q 7.5: Research is useful to every professional	3.83	3.72	0.820
Q 7.6: Research is very valuable	4.50	4.24	0.432
Q 7.7: I will employ research approaches in my profession	4.33	3.62	0.015
Q 7.8: The skills I have acquired in research will be helpful to me in the future	4.61	3.86	0.013
Q 7.9: Knowledge from research is as useful as writing	4.28	4.03	0.364

4.2 Research anxiety

Given the nature of the statements, the greater the degree of agreement with the statements, the greater the respondent anxiety towards research. It follows that the control group (non-participants) has higher anxiety values compared to the group that participated in the I9MASKS summer course (Table 4). The Mann-Whitney tests indicate significant differences in items 8.1– "Research makes me nervous" ($p = 0.027 < \alpha = 0.05$), 8.3 – "Research scares me" $p = 0.008 < \alpha = 0.01$)and 8.7 –" I feel insecure concerning the analysis of research data" $p = 0.012 < \alpha = 0.05$). These results suggest that participation in the I9MASKS project may helped to reduce students' anxiety about research activities and makes them less frightened to carry out research.

Table 4. Research anxiety results.

Research anxiety statements	**Mean**		**Mann-Whitney p value**
	I9MASKS Participant	**Non-Participant**	
Q 8.1: Research makes me nervous	2.39	3.24	**0.027**
Q 8.2: Research makes me anxious	2.72	3.14	0.264
Q 8.3: Research scares me	1.89	2.83	**0.008**
Q 8.4: Research is a complex subject	3.72	3.83	0.719
Q 8.5: Research is complicated	3.33	3.66	0.219
Q 8.6 Research is difficult	3.22	3.45	0430
Q 8.7: I feel insecure concerning the analysis of research data	2.56	3.31	**0.012**

4.3 Positive attitudes towards research

The results of attitudes towards research indicate higher positive attitudes towards research for the group of I9MASKS participants when compared with the control group (I9MASKS non-participant) (Table 5). Mann-Whitney tests confirm significant differences for 6 in 8 statements:

- Q 9.1: I love research ($p = 0.073 < \alpha = 0.10$)
- Q 9.2: I enjoy research ($p = 0.008 < \alpha = 0.01$)
- Q 9.3: I like research ($p = 0.004 < \alpha = 0.01$)
- Q 9.4: I am interested in research ($p = 0.006 < \alpha = 0.01$)
- Q 9.6: Research is interesting ($p = 0.027 < \alpha = 0.05$)
- Q 9.8: I am inclined to study the details of research ($p = 0.030 < \alpha = 0.05$)

These results suggest an increase in the I9MASKS participant's attitude towards research and indicate a possible increase in enthusiasm and interest in research when compared with non-participant engineering students.

Table 5. Positive attitudes towards research results.

Positive attitudes towards research statements	**Mean**		**Mann-Whitney** p value
	I9MASKS Participant	**Non-Participant**	
Q 9.1: I love research	3.61	3.00	**0.073**
Q 9.2: I enjoy research	4.11	3.21	**0.008**
Q 9.3: I like research	4.11	3.21	**0.004**
Q 9.4: I am interested in research	4.39	3.45	**0.006**
Q 9.5: Research acquired knowledge is as useful as arithmetic	3.83	3.72	0.578
Q 9.6: Research is interesting	4.33	3.69	**0.027**
Q 9.7: Most students benefit from research	4.06	3.86	0.395
Q 9.8: I am inclined to study the details of research	3.94	3.17	**0.030**

4.4 Relevance of research to life

The subscale of relevance of research to life has four statements, two positive and two negative:

- For the positive statements, the greater the degree of agreement with the statements, the higher the perceived research relevance.
- For the negative statements, the lower the degree of agreement, the higher the perceived research relevance.

The group of I9MASKS participants has higher levels of perceived relevance than the control group (non-participants), except in statement 10.4 – "Research is irrelevant to my life (-)" (Table 6). Even so, the Mann-Whitney tests only confirmed the existence of significant differences in statements 10.1 – "I use research in my daily life" ($p = 0.053 < \alpha = 0.10$) and 10.2 – "Research-orientated thinking plays an important role in everyday life" ($p = 0.067 < \alpha = 0.10$).

These results are in agreement with those presented previously and suggest that the I9MASKS participants consider use research in their daily lives, unlike the non-participants.

Table 6. Relevance of research to life results.

Relevance of research to life statements	Mean		Mann-Whitney p value
	I9MASKS Participant	Non-Participant	
Q 10.1: I use research in my daily life	3.72	2.97	**0.053**
Q 10.2: Research-orientated thinking plays an important role in everyday life	3.94	3.24	**0.067**
Q 10.3: Research thinking does not apply to my personal life (-)	2.39	2.45	0.673
Q 10.4: Research is irrelevant to my life (-)	1.94	1.66	0.405

4.5 Research difficulty

The last ATR subscale, the research difficulty, has three statements, all negative. In this case, the lower the degree of agreement, the lower the perceived research difficulty. The mean responses of the participant group are lower than the control group (non-participants) except in statement 11.3 - I make many mistakes in research (-) (Table 7). Nevertheless, the Mann-Whitney test found no statistically significant differences between the two groups in the responses to the statements of perceived research difficulty. It is also interesting to notice that both groups have mean values lower than 3, which suggests that both groups do not have major problems in terms of mathematics or research.

Table 7. Research difficulty results.

Research difficulty statements	Mean		Mann-Whitney p value
	I9MASKS Participant	Non-Participant	
Q 11.1: I have trouble with arithmetic (-)	2.17	2.61	0.105
Q 11.2: I find it difficult to understand the concepts of research (-)	2.22	2.50	0.299
Q 11.3: I make many mistakes in research (-)	2.83	2.82	0.747

5 Conclusions

The i9Masks summer project was a novel and successful initiative. Students from the three study cycles had the opportunity to learn from each other by doing research activities in different engineering areas after being confined for so long. Motivated by this initiative and by the commitment shown by students, it was decided to evaluate the impact of this project from the perspective of the students towards investigation.

From the results gathered, significant differences were found in the usefulness of research for career, research anxiety, positive attitudes towards research, and relevance to life indicators, which in turn demonstrates that participants have a further optimistic perspective on research compared to non-participants. Nonetheless, the results for the research difficulty questions prove that although i9Masks improved students' confidence and perspective about research activities, they still acknowledge it as a tough task in some technical aspects.

In general, the results presented emphasize the effect and importance of presenting engineering students to research activities. "Learning by doing" is to go beyond theoretical knowledge and enter the practical field. Although in Portugal, the summer course experiences are still taking their first steps, they have a great potential for applicability and change in the teaching of engineering research. If engineering students have the opportunity to practice the process of solving a practical problem in a laboratory or on a project, they can improve their attitudes towards the engineering research process and increase the recognition of its usefulness and relevance.

> "Tell me, and I forget. Teach me, and I may remember. Involve me, and I learn."
>
> Benjamin Franklin

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