Navigating the Learning Landscape: A Case Study of Multisubject Problem-Based Learning in Computer Engineering Degree

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Abstract: This paper examines the adoption of Problem-Based Learning (PBL) in the degree of Computer Engineering at the Faculty of Engineering. The study presents the degree structure and the curriculum that integrates competencies aligned with the European Higher Education Area, promoting both technical and transversal skills. The case study focuses on the third year of the Computer Engineering degree, highlighting subjects, languages, faculty involvement, and PBL phases. The semester project, a central element, spans multiple weeks, emphasizing interdisciplinary group work and progressive skill development. The semester coordinator plays a pivotal role in managing and evaluating these projects, aligning with continuous and global assessment principles. The academic assessment model includes continuous feedback and aims to enhance students' academic and personal growth.

The results indicate positive perceptions of PBL effectiveness, emphasizing active engagement, interdisciplinary skills, heightened motivation, and comprehensive skill development. Participants express a desire for enhanced resources and support systems, particularly in training, to optimize PBL implementation. As this educational model continues evolving, obtained insights advocate for ongoing adjustments to ensure the continued efficacy of PBL methodologies in preparing students for the challenges of the 21st century workplace.

1 INTRODUCTION

Problem-Based Learning (PBL) is a student-centered teaching approach in which students learn by developing solutions to real-world problems (Savery, 2015). PBL has been shown as an effective approach for fostering deep learning, critical thinking, collaboration, problem-solving, creativity, and teamwork, equipping students with the skills necessary for success in the workplace (Savery, 2015). It is particularly well-suited for Science, Technology, Engineering and Mathematics (STEM) education, where students can apply their knowledge and skills to solve real-world problems. In recent years, there has been a growing interest in PBL as educators recognize the need to prepare students for the challenges of the 21st century (Edens, 2000).

The McMaster University is the pioneer in implementing the PBL methodology. In 1969 the first promotion of the medical school of this university developed real-cases in small groups with interdisciplinary subjects, very few lectures and no exams (Servant-Miklos, 2019a). During this period, this University carried out four curricula that were implemented at McMaster, each of which had a different emphasis on the philosophy, pedagogy, and para-pedagogical manifestations of PBL (Neville et al., 2019). Five years later, Maastricht University adopted McMaster's model, and they implemented the PBL methodology in the medical school. Maastricht University lecturers adopted some changes to improve the experience, which consisted of tutor training, the introduction of the structure of the 7-step method, and the creation of a skills' laboratory (Servant-Miklos, 2019b). Some years later, two Danish Universities adopted the PBL methodology, Roskilde University and Aalborg University. The first applied the PBL methodology

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for ”Basic Education” (2-year studies) for the degrees of Humanities, Social Sciences or Natural Sciences. The studies were fully developed by projects based on problems and developed in a participatory manner (Andersen and Kjeldsen, 2015). When the Danish government approved a regulation so that in universities 50% were master classes and 50% projects, the University of Aalborg implanted the PBL methodology in 1974 (Kolmos et al., 2004). In this context, at the beginning of the century, our university carried out an analysis of the graduate profile with companies in the region. As a result of this analysis, it was concluded that the graduates had high levels of technical performance in the different engineering fields of the faculty. However, among the opportunities for improvement, management, teamwork and, above all, communication skills were identified. After analyzing the different existing methodologies to enhance the competences to be improved, the Aalborg model was identified as a reference. The adoption of the model was carried out progressively during the following courses in the different degrees of the Faculty of Engineering. After 20 years of experience, we continue optimizing and adapting the model to the new learning context. We need to assess these enhancements to confirm that we are heading in the right direction. To investigate the efficacy of PBL model in Computer Engineering education, our study is centered around the following four key research questions:

- RQ1: How do our students perceive our PBL model in relation to the **learning process**?
- RQ2: How do our students perceive our PBL model in relation to the **motivation**?
- RQ3: How do our students perceive our PBL model in relation to the **transversal skills**?
- RQ4: How do our students perceive our PBL model in relation to the **resource appropriateness**?

2 RELATED WORK

This section presents a collection of academic papers on various topics related to PBL. These papers discuss the potentials and challenges of integrating interdisciplinary collaboration into higher education, as well as the cognitive processes related to student comprehension in PBL. Additionally, they present case studies and frameworks for analyzing and facilitating large-scale interdisciplinary projects based on PBL.

In general, there are several works that address the PBL effectiveness in learning, tackling the opportunities or strengths of the learning from different point of view (dos Santos et al., 2020) (O'grady, 2012).

Multiples studies discuss the extra competences the students acquire, which is directly linked with our RQ3; for instance, Carmo-Silva et al. (Carmo-Silva et al., 2018) highlight that students can acquire technical and transversal competences highly relevant for employment through interdisciplinary projects. Still talking about new competences the students acquire, King-Dow et al. (Su and Chen, 2022) discuss the development of STEM cognitive skills through PBL among students at Taiwan's University of Technology. Zhao et al. (Zhao and Wang, 2022) focus on the impact of PBL on student development in middle school chemistry classes. The study explores how PBL influences students' motivation, social skills, and collaborative abilities. It provides insights into the effectiveness of PBL in enhancing students' learning experiences, particularly in the context of science education. Kuo et al. (Kuo et al., 2019) measured the creativity part of the PBL both, creativity on the whole improved and the four facets of creativity (fluency, elaboration, flexibility, and originality) also improved significantly on engineering students, this final work is also linked with our RQ2, as they also measure the motivation.

There are also several works that talk about the importance of interdisciplinary PBLs and how they help students to acquire global competences which are linked to our RQ1; Bertel et al. (Bertel et al., 2022) discuss the integration of interdisciplinarity in education for sustainable development, proposing a framework for analyzing the potentials and challenges of interdisciplinary framing in large-scale projects at Aalborg University. The interdisciplinarity is also tackled as competence enhancement, Tolmos et al. (Tolmos et al., 2021) or Stone (Stone et al., 2018) propose a PBL approach combining multiple subjects, emphasizing the importance of STEM education and its through PBL. There are also great works that tackle the description of incorporation of the PBL in a complete semester as the case of The Industrial Engineering and Management (IEM) program at the University of Minho (Alves et al., 2019) which is linked to our RQ4. They incorporate PBL into its curriculum, involving six courses in the first semester of the first year. They also present results of questionnaires involving the complexity of managing and supporting student teams, assessing their work, and creating a cohesive learning environment, but from the point of view of the instructor.

Linked to our RQ2 and still talking about the interdisciplinary PBLs, Corbacho et al. (Corbacho et al., 2021) explores the development and evaluation of interdisciplinary courses in higher education. They develop a framework for interdisciplinary course design based on constructivism, academic motivation, and social and managing psychology. They implement this framework in six interdisciplinary courses taught to undergraduate students from multiple disciplines. Student feedback from course evaluations and reflective writing exercises indicate that the interdisciplinary courses are effective in developing four key skills and attitudes: teamwork, confident exploration of ideas, personal growth, and relevant perspectives. The courses also foster academic motivation, particularly in the areas of success and caring. The authors conclude that interdisciplinary courses can be valuable additions to higher education, but require careful design and implementation to maximize their impact.

Finally, we also found interesting works related to more general ideas but still linked to our RQs, for instance Navas et al. (Navas et al., 2020) focus on a partnership since July 2017 involving students from SIT (Japan), KMUTT (Thailand), and FCT NOVA (Portugal) in a global PBL event at FCT NOVA which is linked to motivation (RQ2). In the paper by Dolmans et al. (Dolmans et al., 2001), the authors focus on how group work can be effectively integrated into PBL. They emphasize the importance of designing effective cases for a PBL curriculum, which is related to RQ4 and RQ3. The paper likely discusses strategies for creating engaging and challenging problems for group work, ensuring these problems are aligned with the learning objectives of PBL. The authors might also address how to facilitate effective group dynamics and collaborative problem-solving within the PBL framework.

Reviewing these works in PBL underscores the need of adopting the most suitable PBL methodologies and evaluate the implementation with the students. While existing studies highlight the potential of PBL in fostering interdisciplinary competencies and enhancing student engagement, they also identify significant challenges. These include the difficulties in implementation, variable effects on different student groups, and the logistical complexity of large-scale projects. Our work delves deeper, offering insights into how students perceive multidisciplinary PBL as a beneficial and immersive learning approach.

3 CASE STUDY

3.1 Faculty Framework

The Faculty of Engineering adopts the PBL methodology (Kolmos et al., 2004) with the aim of developing both technical and transversal skills in the curricula of its degree programs. The PBL methodology began to be devised and implemented progressively at the faculty in 2002, marked by close collaboration with experts from Aalborg University, who provided valuable guidance for the conception of semester projects with a multidisciplinary nature. Over these decades, a rich variety of experiences have been accumulated in diverse degrees, as well as necessary adaptations to, among others, harmonize with the new European Higher Education Area (EHEA).

Currently, the Computer Engineering degree incorporates the PBL methodology, characterized by the following features:

Semester Project. The six semesters corresponding to the first three courses exhibit a remarkably similar structure in their conception. Each semester begins with a first phase, also known as the lecture period, which includes the teaching of subjects in lecture format, as well as exercises and laboratory practices. This is followed by a second phase, known as the semester project period. In this second phase, the PBL methodology is implemented, which facilitates the execution of multidisciplinary group projects that encompass several subjects simultaneously. It is important to note that the semester project involves all the compulsory subjects corresponding to the semester in question, generally around five subjects. During this stage, the schedule is exclusively dedicated to the semester project, leading to the temporary suspension of regular classes. The duration of the semester project varies according to the academic year, being four weeks in the first year (equivalent to 20% of the semester), six weeks in the second year (representing 30% of the semester), and finally eight weeks in the third year (constituting 40% of the semester). This gradual temporary approach seeks to provide a progressive learning experience adapted to the level of the students at each stage of their training. Therefore, the space given to the project in the curriculum is relevant. And taking the duration of the project in the third year as a reference, each student dedicates an average of 200 hours per semester to the project.

Semester Coordination. Lecturers, who teach together during the same semester, form the team of semester lecturers. In this context, one of the teachers is designated as the Semester Coordinator, who assumes the main responsibility for the integral management of the semester. This teaching team takes on particular importance in the effective administration of the semester. The responsibilities assigned to the team of lecturers includes the task of designing, monitoring and carrying out the evaluation of the semester project. In addition, the team of lecturers also assumes responsibility for coordinating the lecture period. This period, which precedes the semester project, requires careful planning and organization to ensure a smooth and effective transition between the different phases of the academic semester. In order to make the management of these lecturer teams possible, the faculty has provided them with resources and responsibilities. For example, the lecturer team is responsible for managing the timetables of the teaching period subjects and is also endowed with a budget to make the necessary purchases and investments for the development of the students' projects.

Competencies and Learning Outcomes. The degrees were designed on the basis of competencies and learning outcomes, in accordance with the guidelines established in the EHEA. Each technical competency was thoroughly elaborated on the basis of a specific set of learning outcomes. In the interest of fostering a holistic approach to the educational process, the definition of competencies and learning outcomes that were common to all undergraduate degrees within the faculty was undertaken, with special emphasis on the development of transversal competencies. In this context, together with the "traditional" methodologies, the adoption of active methodologies was encouraged, with the aim of enriching and diversifying the learning environment. This integrative approach made it possible to establish a closer connection between the specific competencies of each subject and the transversal skills that are fundamental for the overall development of the student in the academic and professional environment.

Continuous and Global Assessment. The evaluation model was revised according to the new competency model and a continuous and global evaluation was established. This continuous evaluation model involves the progressive evaluation of students through various evaluation milestones, which include exams, individual work, group work and the semester project, among others. Throughout the semester, students monitor their performance, obtaining information about their results through various tests and activities, as well as through the semester project. The results obtained in the first semester are considered preliminary and once the second semester is concluded, a joint meeting of the two lecture teams of the course is held. During this meeting, a detailed analysis of the students' performance is made with the purpose of carrying out an individualized global evaluation. Focusing on the assessment of the semester project, both technical and transversal competences are assessed through a combination of individual and group assessment activities. Individual contributions are assessed through written reports, oral defenses, ongoing monitoring by the instructor, and a peer assessment exercise where students evaluate each other's work. Group contributions are assessed according to the nature of the deliverable (report, video, developed artifacts, etc.). The assessment activity is guided by the assessment rubrics designed by the lecturers. These rubrics incorporate the learning topics of the different subjects involved in the semester, ensuring compliance with the curriculum. Students rely on these rubrics to set project objectives and to measure their progress over the course of the project. In addition, the ongoing nature of the evaluation involves the preparation of specific feedback for each student, providing them with valuable information on their academic performance, and offering guidance for their continued development. This holistic evaluative approach seeks not only to measure students' academic progress, but also to provide them with meaningful feedback that contributes to their constant growth and improvement.

Methodological Fundamentals Subject. Considering the relevance of the semester project in the design of the degrees, it is essential that students correctly internalize the PBL methodology for the development of the semester project. In order to achieve this objective, the undergraduate degrees of the Faculty of Engineering incorporate a compulsory subject in the first year of the academic programs. This subject plays a crucial role in establishing the foundations of the methodology, covering fundamental aspects such as teamwork skills, learning-to-learn, problem-solving, effective oral and written communication, and knowledge of the engineering profile adapted to each specific degree. The course not only lays the theoretical foundations of the PBL methodology but also addresses essential practical aspects. These include the complete process of the PBL methodology, from problem identification to project completion. This process involves key steps such as the definition of the problem, the identification of possible solutions, and the selection and development of prototypes. In this way, the course constitutes a comprehensive framework that, in addition to providing the necessary theoretical knowledge, also guides students in the practical application of the PBL methodology, a fundamental experience for the forthcoming performance throughout their semester projects.

3.2 Course Under Study

The academic semester is structured into two distinct blocks, each characterized by a unique mode of instruction.

3.2.1 First Block: Academic Lectures

The initial block of the semester is dedicated to academic lectures conducted by instructors. During this phase, students attend lectures delivered by faculty members, covering theoretical concepts, principles, and essential knowledge relevant to the subjects of study. These lectures are conducted in a traditional classroom setting, providing students with foundational knowledge and understanding necessary for the subsequent phase of the semester.

3.2.2 Second Block: Problem-Based Learning

The latter part of the semester transitions into a PBL approach in which students engage in hands-on project work. Students apply the theoretical knowledge acquired during the academic lectures to real-world scenarios. This phase emphasizes active participation, collaboration, and practical application of concepts. Limiting the scope of the project to each of the semesters.

Within the PBL phase, students work in teams to conceptualize, design, implement, and present projects aligned with the course objectives. In the absence of direct lectures, students take on greater responsibility for their learning, guided by project guidelines, rubrics, and occasional consultations with instructors as needed.

This shift in instructional methodology from academic lectures to PBL allows students to develop critical thinking, problem-solving and collaboration skills in a practical context. It also fosters autonomy and self-directed learning, as students navigate the project's various phases under minimal direct supervision from instructors.

By incorporating both traditional lectures and PBL into the semester structure, students benefit from a balanced educational experience that combines theoretical knowledge with practical application, preparing them for the challenges and opportunities in the field of Computer Engineering.

This work focuses the study on the third year of the Computer Engineering degree course of the 2022-2023 academic year. The characteristics and data of the course studied are described below.

Subjects and Languages. The first semester of the third year is composed of 5 compulsory subjects: Web Engineering, Operating Systems, Software Engineering, Human-Machine Interface and Project Management. While in the second semester, another 5 compulsory subjects are involved: Web Engineering II, Concurrent and Distributed Systems, Information Systems, Security and Artificial Intelligence. The first semester subjects are all in English, while the second semester subjects are taught in the regional language except for Web Engineering II and Concurrent and Distributed Systems, which are taught in Spanish.

Dates, Students and Faculty. In the 2022-2023 academic year, 24 students were enrolled in the third course. On the faculty side, 5 lecturers were involved in the first semester and another 5 lecturers in the second semester (one per subject). On the one hand the lecturers answer questions from teams in those subjects in which they are experts and on the other hand each lecturer is the mentor of a group, supporting them methodologically in the achievement of the objectives.

Projects Phases. With regard to the semester projects developed, the nine phases established in the methodology were carried out meticulously:

1. Project preparation: in this phase, the team of lecturers teaching compulsory subjects in the semester is responsible for preparing the semester project, including the planning of the main academic milestones, the purchasing of materials and the preparation of the rubric. Special attention needs to be paid to the project rubric, consisting of the assessment criteria for the technical and transversal competences that the students must acquire. Despite the rubric's limitations on certain technological and methodological aspects, it enables the development of projects that can tackle a broad spectrum of challenges. This preparation phase usually takes place months before the start of the semester project.
2. Launch of the project (open project): Students are free to create the teams of five members for the semester project. Project statements are conceived in an open format, allowing each group to identify a problem that particularly motivates them. This freedom of choice is conditioned by the requirement to develop competencies described in the project evaluation rubrics. To further spark their creativity and stimulate the generation of impactful ideas, presentations from entrepreneurship experts are incorporated at the beginning of the project.
3. Problem analysis and approach: During this phase, each team conducts a detailed analysis of the selected problem. To this end, different aspects of the problem are analyzed, such as the context, the causes, the affected people or systems, and the background. Once the problem has been analyzed, it is clearly identified and delimited. Next, each team of students reviews the rubric provided to ensure that with the identified problem, it will be possible to develop all the required learning areas. Table 1 presents part of the

project rubric. Specifically, the assessment criteria for the subject Software Engineering (as an example of technical competence) and the assessment criteria for the video the students prepare to present the project (as an example of transversal competence).

4. Select and investigate solutions: Based on the delimited problem, each student team conducts research on potential existing solutions, ensuring rigorous justification of the sources consulted. In addition, they define their own solution, emphasizing the distinctions from the identified existing solutions and highlighting the added value of their chosen approach. Each team of students validates with the lecturers who are experts in each subject that the proposed solution will allow them to develop the competences required in the rubric. Once the problem analysis and solution proposal phases have been completed, the results are presented in a public defense to the team of lecturers, who provide valuable feedback on the proposal.
5. Experimentation and follow-up: This phase, the most extensive of the project, involves the student team building a prototype that reflects the characteristics of the solution and validates the proposal. Throughout this stage, each team makes several presentations to the team of lecturers to expose the technological proposal of the project and the different milestones of progress achieved. These intermediate milestones are evaluated by means of corresponding feedback.
6. Project closure and deliverables: Each project team concludes the developments and delivers to the teaching team the results obtained, together with the project report. These materials are analyzed and evaluated by the team of lecturers based on the previously established rubrics.
7. Presentation and Defense: Students use various resources to present the project, addressing aspects such as the description of the problem to be solved, market analysis, the proposed solution and its added value. The presentation usually includes a demonstration of the prototype developed, as well as the conclusions and future lines identified. In addition, an individual defense of the degree of learning obtained thanks to the project is carried out.
8. Evaluation and Final Feedback: The team of teachers carries out an exhaustive analysis of the results obtained both at group and individual level in the project, elaborating a final feedback for the students. The degree of acquisition of technical competences is assessed individually through the defense. While different group aspects, such as the product, presentations, technical report and teamwork are assessed with group marks. In order to be eligible for a weighted mark that takes into account both parts (individual and group) it is necessary to pass the individual defense. The results of the grades, as well as the formative feedback on the various evaluated aspects, are communicated in a meeting between the mentor and the student team.
9. Semester Closure (PBL Review): The teaching team examines the strengths and possible areas of improvement of the project, considering the lessons learned for the planning of the next year's project.

During the PBL phase of the semester, students undertake a variety of innovative projects aimed at applying their theoretical knowledge to real-world challenges. Examples of such projects include the optimization of land use for labor purposes based on artificial intelligence, the development of an intelligent service for receiving climatological and geological alerts, the creation of an analyzer and optimizer for sleep patterns with user recommendations, the implementation of an intelligent assistant for diagnostic procedures using radiography, the design of an intelligent Parking system for more efficient guidance and pricing calculations, the development of a strategic system for analyzing Formula 1 races, and a proposal for improving bus transportation in small communities. These projects not only showcase the students' technical skills but also demonstrate their ability to address practical issues with creativity and innovation, thereby preparing them for the complexities of real-world engineering challenges.

4 EVALUATION

To assess the influence of interdisciplinary PBL, we conducted an evaluation focusing on four Research Questions: learning process, motivation, transversal skills, and resource appropriateness. That evaluation was performed using a questionnaire.

4.1 Questionnaire

The construction of the questionnaire for this study involved a comprehensive review of existing literature to identify and adapt relevant questions from previous research studies. We selected 4 papers (Mihic and Zavrski, 2017) (Kim, 2015) (Usmani et al., 2011) (Assaf, 2018) as a baseline for the questions. We grouped

Table 1: Illustrative part of the rubric used in the evaluation of the first semester project, where the levels of a technical competence (corresponding to the subject Software Engineering) and the levels of part of the transversal competence of communication (corresponding to the video of the project produced by the student team) are provided.

Subject	Evaluated Concepts	Insufficient	Pass	Remarkable	Outstanding
Software Engineering (Technical)	Know how to apply techniques and tools for verification and validation	Very initial testing process: (very low coverage, very bad structure of testcases, very low quality in testcases, not usage of mocks for unit testing) No use of SonarQube and SonarLint	Initial testing process: (low coverage, bad structure of testcases, low quality in testcases, not usage of mocks for unit testing) Use of SonarQube and SonarLint	Acceptable Cyclomatic Complexity, Code Smells, number of Bugs, number of Vulnerabilities and medium Test coverage (good structure of testcases, good quality in testcases, some usage of mocks for unit testing and some refactoring)	Low Cyclomatic Complexity and Code Smells, 0 Bugs, 0 Vulnerabilities and very high Test coverage (good structure of testcases, high quality in testcases, usage of mocks for unit testing, refactoring)
	Know how to apply configuration management techniques and tools	No use of any continuous integration tool (Jenkins, GitLab) No use of git + no correct branching strategy	Use of any continuous integration tool (Jenkins, GitLab) to run tests automatically after merge in the appropriate branch Use of git + branching strategy	Use of any continuous integration tool to automate SonarQube analysis (basic)	Use of any continuous integration tool to automate SonarQube analysis (advanced)
Video (Transversal)	Format and duration	Does not respect the required format (sale)	It respects the required format (sale), but the video exceeds or falls short for more than 60s.	It respects the required format (sale), but the video exceeds or falls short by more than 30s.	Respect the required format (sale), and the total time of the video is met.
	Content	Less than 5 sections of the requested script appear in the video.	Respect the script, the 5 requested sections appear.	Respect the script, the 5 requested sections appear, although the timing is not correct.	Respect the script, the 5 requested sections appear in correct timing.
	Sale	Not convincing messages and people, no sale is achieved.	The messages are mostly convincing and the sale is generally correct, but there are parts of the video that are slow or uninteresting.	The messages are convincing, but people do not convey ”naturalness” and/or ”confidence.”	The messages are convincing and so are the people (naturalness = be yourself and confidence).
	Correctness	Many spelling and/or grammatical errors in the voice-overs, and poor video quality. The result is insufficient.	There are more than 4 spelling and/or grammatical mistakes in the locutions, the video quality in more than 2 sections is not good. But the result is interesting.	There are less than 4 spelling and/or grammatical mistakes in the phrases, the quality is generally good. But there are some poor quality sections.	There are no spelling or grammatical mistakes in the phrases. The overall quality of the video is excellent.
	Originality	Little originality, the result is unattractive.	The product and the sale made are not original, but the result is good.	The product shows a certain originality. The work demonstrates the use of new ideas and insight.	The video and the sale mode are very original and creative.

their questionnaire items according to their alignment with the focal aspects of our investigation. Subsequently, items were selected and adapted from various sources to ensure the questionnaire's suitability in probing the targeted dimensions pertinent to our research focus on PBL. While several papers provided valuable insights and questionnaire items, a specific study was omitted from consideration due to its distinct focus, which did not fully align with the specific dimensions and objectives delineated for our investigation into PBL. This process aimed to ensure that the questionnaire utilized in our study precisely addressed the intended facets of PBL experiences under scrutiny, fostering a robust and tailored instrument for data collection. The list of the questions grouped by the 4 key areas can be found in table 2.

Student perception surveys can serve as a formative assessment tool for instructors and curriculum developers. Feedback from students can identify strengths and weaknesses in PBL implementations, allowing educators to make informed adjustments to enhance the learning experience (Wallace et al., 2016).

4.2 Participants

Out of the 24 students, the group consisted of 23 males and one female. The age range of the participants was 20–24 years, reflecting the usual age of third-year Computer Engineering students.

4.3 Procedure

The participants answered the questionnaire during their individual defenses of the 2nd semester, on June 16th. A briefing on the questionnaire was conducted first, and participants had 20 min to answer all the questions afterward.

5 RESULTS

The comprehensive breakdown of each question organized by the defined four areas, along with its corresponding mean value and standard deviation, is presented in Table 2. Figure 1 show the distribution of results of the questionnaire.

The internal consistency of the questionnaire was evaluated using Cronbach's alpha coefficient, yielding a high value of 0.936, indicating a substantial level of internal consistency among the survey items measuring satisfaction within the sample of 24 students. However, it is essential to acknowledge the potential limitation associated with the small sample size, which may restrict the generalizability of the findings.(Tavakol and Dennick, 2011).

The overall mean rating of the questionnaire was 3.70/5.

Participants indicated a strong inclination towards perceiving PBL as an effective educational approach (Q1, Q6; Mean: 4.00-4.17). The responses suggest that PBL fosters an environment propitious to active engagement and interdisciplinary knowledge acquisition (Q3, Q4, Q5, Q6, Q7; Mean: 3.61-4.00). Moreover, it encourages students to transition from passive learning to becoming active processors of information, stimulating cooperative problem-solving (Q2, Q3, Q7; Mean: 3.74-4.09). The low standard deviation values (0.51-0.99) suggest that there is a high degree of consensus among students regarding their responses to the "Learning Process" questions.

While participants generally acknowledged a moderate increase in motivation due to PBL (Q8, Q9, Q10, Q11; Mean: 3.26-3.91), there were indications that a prolonged PBL period or extension might positively impact motivation (Q12; Mean: 3.48). Choosing PBL theme (problem to be solved) and being multi-subject appeared to contribute significantly to enhancing motivation levels (Q9, Q10; Mean: 3.26-3.52). Apart from question 11, which specifically addressed the level of commitment (Std Dev: 0.45), the standard deviation values for the "Motivation" questions (Std Dev: 1.38-1.62) indicate a lower degree of consensus among students regarding their responses.

Responses also shed light on the broader skill set development facilitated by PBL. Participants perceived improvements in decision-making, teamwork, time management, and communication skills (Q14, Q15, Q17, Q18; Mean: 3.39-4.26). Notably, PBL's effectiveness in preparing individuals for real-world applications and enhancing their ability to manage complex tasks was highlighted (Q13, Q16; Mean: 3.87-4.17). The freedom and creative space offered during PBL projects seemed to encourage innovative thinking, critical evaluation, and effective planning (Q19; Mean: 3.52). In the "Transversal Skills" section of the questionnaire, there was a relatively lower degree of consensus among students regarding their responses to the question about improving the ability to speak in front of people (Std dev: 1.40), but a high consensus on the rest of the questions (Std Dev: 0.47-0.90).

Feedback on the resources and support systems related to PBL implementation revealed moderate satisfaction levels (Mean: 2.87-3.61). While participants generally acknowledged the expertise of tutors (Q20, Q21; 3.57-3.61), there were indications of a need for more comprehensive training before PBL implemen-

Table 2: Results of the Questionnaire.

		Question	Mean	Std Dev
Learning Process	1	PBL is a more effective learning method.	4.17	0.51
	2	PBL makes you more active in cooperative learning for problem-solving.	4.09	0.54
	3	PBL helps you to move from being a passive learner to an active whole-life learner.	3.74	0.84
	4	PBL helps you take responsibility for your own learning.	3.91	0.90
	5	PBL students decide for themselves the learning goal.	3.61	0.99
	6	PBL helps you acquire interdisciplinary knowledge.	4.00	0.73
	7	PBL helps you become an active processor of information.	3.87	0.75
Motivation	8	PBL has increased your motivation for studying.	3.35	1.60
	9	Establishing the PBL theme increases your motivation.	3.52	1.53
	10	A multi-subject PBL increases your motivation.	3.26	1.38
	11	Working on projects increased your level of commitment.	3.91	0.45
	12	PBL period should be extended.	3.48	1.62
Transversal Skills	13	PBL better prepares you to work in industry.	4.17	0.51
	14	PBL has improved your teamwork skills.	4.26	0.47
	15	PBL has improved your decision-making skills.	3.91	0.90
	16	PBL has helped you identify weak points for improvement.	3.87	0.66
	17	PBL has improved your ability to speak in front of people.	3.70	1.40
	18	PBL has increased your ability to manage time effectively.	3.39	0.52
	19	During the PBL period, you have been able to plan, apply, evaluate and be more creative with greater freedom.	3.52	0.81
Resource Appropriateness	20	You are satisfied with the experts' knowledge on the subjects.	3.61	1.25
	21	You are satisfied with the help you have received from your tutor.	3.57	1.08
	22	You received adequate training on PBL prior to its implementation.	3.30	1.04
	23	You are satisfied with the evaluation methods.	2.87	1.66

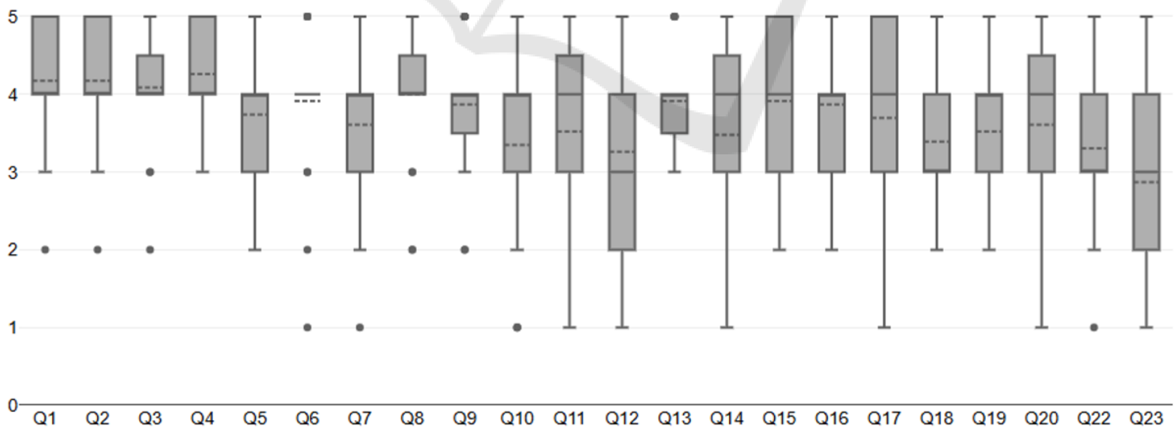

Figure 1: Distribution of results for each of the 23 questions of the questionnaire.

tation (Q22; Mean: 3.30) and that evaluation method could be improved (Q23; Mean: 2.87). The consensus on the questions about "Resource Appropriateness" was low (Std dev: 1.04-1.66).

In conclusion, the study's findings underline the effectiveness of PBL in promoting active learning, interdisciplinary knowledge acquisition, and skill development. While it significantly contributes to motivation, skill enhancement, and overall learning experience, improvements in resource appropriateness, particularly in prior training and evaluation methods, could further enhance the efficacy of PBL implementations. These insights advocate for continued refinement and better structuring of PBL programs to harness their full potential in fostering holistic learning experiences.

6 CONCLUSIONS AND FUTURE WORK

The implementation of PBL at the Faculty of Engineering stands as a testament to its evolution from pioneering institutions like McMaster, Maastricht and Aalborg Universities. Our PBL methodology, a distinctive feature of the curriculum, demonstrates a progressive and immersive learning experience. The semester coordinator's role in managing these projects underscores the commitment to holistic student development. Continuous and global assessment principles, including ongoing feedback and meticulous evaluation, contribute to a dynamic educational environment that goes beyond traditional academic metrics.

As the study zooms into the specific case of the third year in the 2022-2023 academic year, the detailed examination of subjects, languages, faculty involvement, and project phases provides a microcosm of the broader PBL implementation. This case study illuminates the meticulous planning, execution, and evaluation involved, showcasing the university's commitment to providing a rich, immersive, and effective educational experience.

Our findings affirm the efficacy of PBL in empowering learners to take ownership of their educational journey, setting their learning goals, and cultivating a comprehensive understanding across subjects. Regarding motivation, our results suggest that refining PBL structures to further boost motivation could yield substantial benefits in student engagement and commitment to the learning process. Moreover, ensuring adequate training and support for both tutors and students could potentially enhance the overall experience and outcomes of PBL initiatives. Considering the constraints posed by the scope of this case study and the dynamic nature of student experiences, it is advisable to pose this question periodically to observe and trace its evolutionary trajectory.

In our continuous efforts to enhance our educational approach, we are exploring avenues to reinforce our curriculum with the SDGs, demonstrating our commitment to global sustainability and responsible citizenship. Our focus is on promoting environmental and social consciousness through educational practices.

Additionally, we are actively working towards a more robust integration of corporate visions within our PBL. Collaborations with local companies will enable us to bring authentic, real-world challenges into our classrooms, fostering a dynamic learning environment that directly addresses industry needs. This strategic alignment not only will enhance the practical relevance of our programs but also will strengthen the bridge between academia and the professional landscape.

Moreover, to empower our students with a deeper understanding of their progress and skills development, we are placing a greater emphasis on self-assessment within the PBL process. This approach will encourage students to take ownership of their learning journey, promoting reflection and self-directed growth for a more comprehensive educational experience.

Furthermore, the lowest score in the questionnaire was related to the evaluation method (Q23), showing the difficulty of evaluating this kind of work. For the future, we have identified the need to improve the system for continuous evaluation and feedback throughout the PBL process.

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