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INTEGRATING PROJECT-BASED LEARNING INTO THE GEN Z CIVIL ENGINEERING CURRICULUM: CASE STUDY AT ESTP SCHOOL OF ENGINEERING

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Abstract. Generation Z (Gen Z) refers to more than 2 billion people born between 1995 and 2012, who have grown up immersed in digital innovation and are familiar with numerical tools from a young age. Gen Z gives a significant importance in their practices to environmental issues, sustainable practices, well-being, and work-life balance. As Gen Z enters higher education, professors face challenges in motivating students by tailoring their approach to academic engagement. In this context, ESTP School of Engineering incorporates the Project-Based Learning (PBL) approach into civil engineering courses, allowing students to apply theoretical knowledge to real-case scenarios. This article explores the challenges faced by higher education in engaging Gen Z students and the strategies adopted to motivate them to pursue and succeed in their civil engineering education. The advantages and difficulties of integrating projects into civil engineering curricula are discussed, focusing on how project-based approaches enhance student engagement and prepare students for their professional careers. This paper examines the implementation of Project-Based Learning in civil engineering courses at ESTP, highlighting examples of successful projects, innovative teaching methods, and assessment strategies designed to maximize learning outcomes. By emphasizing real- case studies, students have the opportunity to apply engineering principles to solve complex problems while developing critical thinking, teamwork, and creativity. The integration of projects into coursework not only enhances students' technical skills but also prepares them for the collaborative and multidisciplinary demands of the civil engineering profession. This paper demonstrates how project-driven education can enrich the learning experience and better equip future Gen Z civil engineers for the challenges they will face during their career.

1 INTRODUCTION

Civil engineering field is very complex. It concerns the modern infrastructure development, responsible for designing, constructing, and maintaining the built environment that sustains society. From bridges and highways to water management systems and urban development, civil engineers play a critical role in our daily lives. As the challenges faced by the profession become more complex, ranging from sustainability and climate change to increasing urbanization and technological advances, the education of civil engineering students must evolve [1].

Traditional teaching methods in civil engineering have historically been centered around lecture-based instruction, structured exercises, and laboratory experiments. While these approaches have successfully provided students with essential technical knowledge, they have often been criticized for fostering a passive learning environment, where students focus more on memorization and rote learning than on developing critical thinking, problem-solving, and collaborative skills [2].

Studies showed that The implementation of PBL led to significant improvements in student performance and engagement [3]. At Universitat Politècnica de Catalunya, the implementation of the PBL approach in a reinforced concrete course of civil engineering involved students working in teams [4]. Surveys showed that by adopting this new approach, the percentage of passing students increased from 55% to 96% while the mean final grade rose from 4.7 to 7.2, with a reduction in grade variability, indicating more consistent student performance [4]. Students found the course intellectually stimulating and reported valuable learning experiences. They also noted improvements in teamwork and communication skills. Interviews indicated that students enhanced their leadership, time management, critical thinking, and entrepreneurial skills through the PBL approach.

At McMaster University, the implementation of Problem-Based Learning (PBL) reduced traditional lecture-based teaching by engaging students in real-world problems [5]. In this approach, students worked in small groups to analyze the problem, identify learning objectives, and research relevant information. This method encourages self-directed learning and the development of critical thinking skills. Faculty members act as facilitators, guiding students through the learning process rather than delivering content directly. The program has been successful in fostering a deeper understanding of the material, improving retention, and enhancing students' ability to apply knowledge in practical situations. It has also been associated with increased motivation and engagement among students. The success of McMaster's PBL model has led to its adoption in various disciplines beyond medicine, including engineering, business, and education, both within Canada and internationally. Overall, the McMaster Problem Solving Program demonstrates the effectiveness of PBL in developing essential problem-solving skills that are crucial for professional practice [5].

However, the effectiveness of PBL can vary based on implementation quality and contextual factors. Professor may face difficulties in adapting courses to the PBL approach, requiring professional development and support. PBL requires significant planning and resources, which can be challenging in some educational settings [6].

The criteria for accrediting engineering programs document by ABET outlines the standards for accrediting engineering programs [7]. These criteria ensure that programs meet established educational quality benchmarks, preparing students for professional practice. These criteria cover essential areas such as curriculum design, student learning outcomes, faculty qualifications, continuous improvement processes, institutional support, and resource adequacy. Programs are expected to define clear educational objectives and assess student achievement regularly to align with industry expectations. In addition to general standards, ABET also includes discipline-specific criteria that reflect the unique demands of various engineering fields. For master’s-level programs, added emphasis is placed on advanced coursework, research, and professional development. Overall, the criteria aim to promote excellence, accountability, and adaptability in engineering education.

2 OBJECTIVE

The objective of this study is to examine the integration of Project-Based Learning (PBL) into the civil engineering curriculum. As engineering education continues to evolve toward more student-centered and competency-based models, PBL provides a valuable framework to bridge theoretical instruction with real-world application. To illustrate this approach, a case study was conducted involving over 500 undergraduate civil engineering students at ESTP School of Engineering, who participated in multidisciplinary projects over an academic year. These projects, ranging from digital simulations to experimental laboratory work and site visits, were designed to reflect real engineering challenges. The study documents the design and implementation of the PBL framework, analyzes organizational and pedagogical constraints such as classroom and laboratory scheduling, and highlights the measures taken to support student collaboration, including group restructuring when necessary. The research aims to assess the effectiveness of PBL in achieving targeted learning outcomes and to provide practical recommendations for its broader adoption within engineering education.

3 METHODOLOGY

To explore the effect of integrating Problem-Based Learning into civil engineering curriculum at ESTP school of Engineering, a new course was conducted within an undergraduate engineering curriculum. This case study aims to illustrate how PBL can be effectively embedded into course design and the pedagogical strategies adopted to support active learning. The following section outlines the structure of the course, the implementation process, and the methods used to assess both student engagement and learning outcomes. This article presents the PBL approach adopted during the fourth year of engineering curriculum.

The primary question that emerged is which method to adopt for implementing PBL using a competency-based approach. To determine the working methodology and pedagogical objectives, a scientific committee consisting of academic researchers, industry partners, and faculty members is established. The role of the scientific committee is to define the working methods, determine the relevant subjects, and point out any potential difficulties that might be encountered.

The first step of the implementation consists in analyzing the existing engineering curriculum in order to identify adequate courses where PBL fits. Once the courses are chosen, the learning outcomes are defined and the assessment strategy is set. After analyzing the courses content, the scientific committee decided to incorporate a continuous and progressive project, aiming to mobilize various skills acquired through coursework. The goal is to rely on theoretical knowledge to support the project's development. This requires careful and strategic planning of the courses all over the academic year.

The committee analyses past project experiences and identify the most suitable methodology to implement. Following extensive discussions, a decision was made to incorporate a “research and engineering project” that offers several topics directly related to the students' field of study.

This project requires a diverse set of competencies that reflect both technical expertises and soft skills. Core technical skills include structural analysis, geotechnics, materials, hydraulics, urban design, numerical technologies, etc. While soft skills include teamwork, project management, etc. Developing these skills through PBL allows students finding efficient solutions to nowadays problems. Based on the course objectives, the below competencies are identified using Bloom's Taxonomy [9] :

1. Identify key terms in order to conduct a structured literature search using scientific databases
2. Select and implement an appropriate design based on the identified problem
3. Set up a research methodology by collecting and analyzing accurate Data
4. Design a construction project by adopting a performance- oriented approach at different scales (material, construction system, and urban system), integrating uses and regulations
5. Develop original engineering solutions considering ethical aspects and sustainability
6. Produce comprehensive reports, technical documents, scientific poster that present the work and respect presentation guidelines
7. Communicate effectively orally and demonstrate strong response skills in front of the jury
8. Ability to work by group and continuous learning

Faculty members and industry partners agreed to propose projects based on actual professional scenarios. Since ESTP provides majors in multiple disciplines, the project topics proposed must align with one of the following areas:

- Urban Strategies & Management
- Decarbonized Infrastructure
- Sustainable Materials
- Sustainable Structures
- Innovative Solutions & Technologies for Constraction

To offer educational and practical benefits, projects are proposed by group. Working by group encourages teamwork and collaboration, mirroring real-word industry practices. It promotes interdisciplinary learning since students from the same group follow different majors. Experiences at ESTP showed that a group of four students is considered optimal. This size allows an efficient distribution of workload among the group members. The roles can be clearly defined which enhances the collaboration. Smaller groups can face difficulties because of the workload while bigger groups can face coordination issues.

This project is integrated into the academic curriculum and spans the entire academic year during the fourth year of study. The total number of hours allocated to the project is 90 hours scheduled in a fixed time slot as follows: 30 hours during the first semester from October to January and 60 hours during the second semester from February to April.

At the beginning of the first semester, an exchange workshop is set to help students choose their projects and integrate a group work. During this session, students assist to a presentation where all projects are listed and followed by a dedicated time for discussion. This allows students to discuss with the professors and to build their team. They can ask their questions to better understand the proposed subject and make their choice.

Once the groups are set, students can start their projects. During the first semester, students have to analyze the research context and produce a review of the state of the art. The main target from this work is to elaborate a research methodology that is rigorous and appropriate to the identified research question. Students should search, read, analyze and synthetize related scientific documents. In order to provide them with the adequate research methodology, students must follow a 3 hours' theoretical course. This course offers a comprehensive introduction to research methodologies emphasizing the critical analysis. Students learn how to search for pertinent information based on relevant databases and the adequate methodologies to construct bibliographies. Students explore the use of artificial intelligence tools in academic work. Professors highlight the potential ethical challenges that should be respected in research and while using the artificial intelligence.

Once the theoretical aspects are explained, students should follow project follow-up sessions. During these sessions, students should present their work progress and ask questions to professors. Intermediate deliverables are requested to help professors monitoring the students' progress. This methodology enables professors to identify potential difficulties faced by students and to provide effective monitoring. At the end of the semester, students should be able to present their research analysis and methodology to be adopted during the next semester. Three deliverables are requested: 1- Literature review, 2- Research Methodology, 3- Presentation material. At the end of the semester, students should present their work by group. They are evaluated based on a group grade and an individual grade. A Standardized competency-based assessment grid is used for all projects.

During the second semester and once the theoretical part is finalized, students can apply their research methodology. Since some projects involve laboratory experiments, the scientific committee decided to schedule 60 hours. Laboratory research projects require access to specialized equipment, materials and controlled environment to do experiments. Long time experiments consist one of the main challenges for scheduling courses. Because of that, five consecutive hours are scheduled per week. During these hours, students can do experiments, make numerical simulations, collect data and analyze them. Due to safety considerations and the need for adequate supervision, faculty presence is mandatory during all the sessions. The project outcomes were compiled into a comprehensive technical report, including the background, methodology, results, discussion, and references. Students also prepared a presentation to communicate their work to faculty, peers, and external evaluators. A poster session was held in order to present the class work.

4 ADVANTAGES AND DIFFICULTIES

Selected focus exchange groups and semi-structured interviews were conducted to gain deeper insight into student experiences and perceptions. The results show the effectiveness of the PBL integration through outcome-based criteria, such as skill development, teamwork, problem-solving ability, and student engagement.

As a result, students expressed their satisfaction. Through the PBL approach, they are able to work on real case engineering challenges familiarizing them with the professional practices. They can rely on their theoretical knowledge learned through their academic courses to implement the project. They can develop their technical skills in their specialties. Students are happy to collaborate in teams which allow them to develop their communication skills and knowledge. Since there are some international students that integrates ESTP at the beginning of the academic year, working by group helps them integrate more easily into their class. These research projects encourage innovative thinking by enhancing problem-solving and innovation skills. All over the year, students were able to develop their critical thinking in order to find solutions to identified research problem. They appreciate the opportunity to visit construction sites, enhancing the practical aspect of their work.

Implementing PBL in the civil engineering curriculum presents several challenges. One major challenge is making sure that each project incorporates all the required competencies. The projects are very diverse, ranging from digital to experimental work and covering various fields. Professors may find difficulties to shift from traditional course to PBL, often due to lack of training or resistance to change. Another difficulty is the scheduling of project groups in standard classrooms or laboratories, which has proven to be highly complex. With more than 500 students participating, the process demanded significant logistical effort to ensure adequate planning and execution of the overall project. In very limited cases, some students expressed difficulties working in teams. In these cases, professors have to take necessary measures to create a more supportive environment, such as changing groups or reorganizing them.

12 CONCLUSIONS

- The study concludes that PBL is an effective pedagogical strategy, particularly during civil engineering education at ESTP school of engineering. It not only improves academic performance but also fosters the development of essential professional skills. Integrating the “research and engineering project” bridge the gap between theoretical knowledge and real- world application and allows students to be prepared for complex demands of the profession. This initiative enables them to engage with real-life cases that align with their career aspirations. The implementation of PBL demonstrates that when students engage with authentic engineering problems, their motivation and engagement significantly increase, leading to stronger retention of both technical knowledge and transversal skills such as communication, teamwork, and project management. Future research could examine the integration of PBL into numerical projects exploring the role of digital tools, interdisciplinary partnerships, and co-teaching models. This approach could offer innovative pathways for scaling PBL while maintaining quality and relevance into engineering curriculum.

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