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An Investigation into the Efficient Engineering Study Using Project Based Learning

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ABSTRACT

Despite a large body of learning studies indicating incompetence, the major paradigm for engineering instruction is still written about and spoken about. Traditional methods of structural engineering education place a strong focus on the transfer of structural engineering theories and the behaviour of common construction materials. Different universities put different emphasis on design projects; nonetheless, they are often assigned to the last year of study. Exams are often given more weight in evaluations than project work. In recent years, the engineering industry and organisations have lobbied for changes in assessment, and the engineering industry and organisations responsible for accrediting engineering schools have advocated for improvements in teaching practises. According to this study, using engineering processes in engineering structures is an effective learning strategy that reflects industrial practise. Through projects, students learn how to integrate stability analysis, resource performance and accessibility, constructability, and economic realities into the professional practise of engineering structures.

Keywords: Engineering Education, Project Based Learning, PBL Framework, PBL Elements.

1. Introduction

According to industry consensus, engineering students were not learning the necessary skills for the workplace. Because most engineering professions require both creation and practise, the educational system should focus on preparing students to meet industry demands. The manufacturing sector thrives as a result of its ability to design, manufacture, and sell cutting-edge products. For these items to be effective in the market, "both time and quality are required, and both are dependent on the product design." Modern engineering educational institutions produce engineers who are excellent scientists—well-versed in mathematics, engineering science, analytical procedures, and research—but who are poor at designing

components, procedures, or networks [1]. Bringing the industrial environment into the classroom has several advantages: a design engineer's learning curve is shorter, there are fewer design errors, and the design is more cost-effective and practical. Mechanical engineering tasks are inherently complicated, ill-defined, and difficult in the real world. To deal with the complex problems that mechanical engineers face in the real world, university graduates must be educated and trained using a project-based learning (PBL) method.

As an inquiry-based learning strategy, Project-Based Learning allows students to use their officially acquired solutions to understand ill-defined tasks that are provided with less information and require minimal supervision from a facilitator (a more experienced person). For the product design programme, various techniques for teaching product design were tried, and formative assessment methodologies were used. According to the research [2], there are four major advantages to using project-based learning as a teaching method in engineering education. For starters, just like in a traditional classroom setting where manufactured issues are used, Project-Based Learning encourages students to participate in addressing complicated, ill-defined real-world situations where multiple answers are expected. Second, project-based learning allows students to collaborate on ill-defined real-world issues, fostering critical thinking and collaboration skills. Third, project-based learning allows students to work on real-world problems, allowing them to develop skills that will help them succeed in their careers.

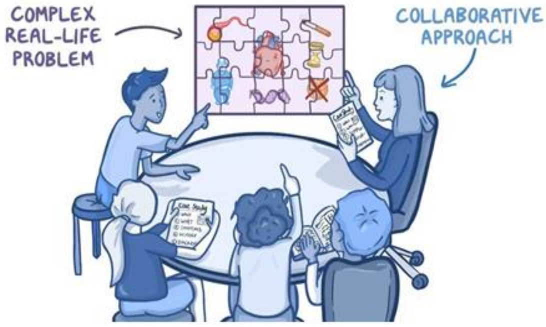

Figure 1: Project-based learning (PBL) method to deal with the complex difficulties

Incorporating real-world scenarios into Project-Based Learning motivates students to engage in active learning and promotes long-term information recall. Finally, Project-Based Learning promotes the integration of theory and practise by demonstrating how perspectives can be used to discover solutions to ill-defined real-world situations. Kapusuz and others argue that project-based learning is a more effective approach for integrating institutional curricula and workplace skill requirements [3]. In this study, we believe that the technical education design curriculum should provide students with opportunities to understand systems engineering as it is done and emulated in the industry. These opportunities could be provided through project-based learning. "Students, industry, and accreditors would all benefit equally from any improvement to the current lecture-centric programmes that dominate engineering," says Barroso. The key question addressed in this study is, "How well does project-based learning in an undergraduate engineering class promote the development of manufacturing engineering abilities required in the workplace?"

Much like in the 1950s, lecture-based approaches dominate instructional methodology, presentation, and teaching, much as they did in the 1950s. Engineers are now expected to handle increasingly complex problems, which necessitates the development of critical thinking and questioning skills, as well as the ability to interact effectively and work in diverse teams [4]. Industry demands for engineering graduates have shifted over time, necessitating changes in educational methodologies. Contextualized, independent, multidisciplinary learning, and student-centred processes may help students learn more effectively by presenting situations similar to those they will face in the workplace. Following the Bologna Declaration, all European institutions began using innovative, proactive teaching and learning approaches to help their students succeed in their successful jobs. The Bologna approach has led to the most important changes in higher education in modern times. This has led to a lot of changes in the curriculum, institutions, and pedagogical paradigm.

PBL is a proactive learning methodology that has grown in popularity in engineering education (EE) due to its positive impact on student learning and engagement. The learner is central to project-based learning. Rather than employing a rigorous lesson plan that steers a student along a predefined route of learning objectives, project-based learning allows for in-depth exploration of a subject [5]. The technique has been described as one of the most successful engineering teaching methods in the literature. This method of instruction helps students develop their intellect, abilities, and perspectives. There have been numerous successful examples of project-based learning implementation in engineering education documented in the literature. Because of the Bologna Process criteria, the majority of them took place at European universities. In poor countries, the use of project-based learning in engineering education is still largely unexplored [6]. Furthermore, as the economies of developing countries improve, there is a greater demand for individuals with multidisciplinary experience in technology-related fields, as well as revisions to present teaching approaches in degree programmes. In this light, the purpose of this study is to talk about the experience of implementing project-based learning at a university in a developing country. The research focuses on the perception of the University of Sao Paulo's Polytechnic School's "Product and Process Design" course. The course is taught over the course of one semester as part of a five-year process engineering undergraduate programme. Project-Based Learning has improved the learning experience in product and process design courses. It may benefit the country by better preparing young engineers for industrial settings. Employers recognise the value of project-based learning education, and graduates may be able to start working immediately after graduation.

2. Elements of PBL

After reforming their core educational beliefs and assumptions, educators should carefully prepare for the following factors in order to successfully implement PBL in their classes: A lapse in either of these factors could hurt learning, making students less interested in their studies or disengaged from them.

Figure 2: Element of project-based learning (PBL)

1. **Problem design**:

Complicated, open-ended, and realistic projects should include a variety of solutions and methods for achieving those solutions while connecting with students' experiences. The projects should include a time-consuming, advanced stage in which students formulate questions, find and use resources, ask follow-up questions, and construct their responses. The projects should be in a real-world setting, use real-world procedures and resources, including quality standards, have a real-world impact, and be related to the issues, interests, and personalities of the students. They should require learners to apply theoretical concepts and encourage them to combine information from multiple courses [7]. They should be designed to increase the likelihood that students will encounter the key concepts outlined in the learning goals and syllabus, as well as to encourage students to confront and resolve opposing ideas in order to avoid "doing for the sake of doing." Several initiatives should consider not only technical factors, but also economic, sociocultural, and ethical factors. As part of the project, students should be required to demonstrate what they have learned by creating concrete prototypes that are presented or provided to individuals outside of the classroom. The proposed project or goal should not be overly specific about the answer or what should be created. As part of their projects, students should be able to research the background, identify limitations, research multiple sources, and come up with a variety of possible solutions [8]. Projects should let students make decisions about the models they build, how they work, and how they spend their time, guided by the teacher and based on their knowledge of PBL.

2. **Task**:

Projects must be divided into tasks, each of which explains what will be done and properly integrates the subject to be researched. Such activities should be enjoyable, challenging, and attainable.

3. **Process:**

Activities that necessitate an analysis method, synthesis, and evaluation should be included in the processes required to complete the job. To reduce the possibility of "doing without conceptual knowledge," each project should include extensive study of high-quality text or literature as well as practise with a variety of challenges.

4. **Cooperative/Collaborative learning**:

There must be a lot of rounds of peer review or team brainstorming workshops in the project activities.

5. **Resources:**

Various learning materials, such as data, study materials, and exemplary work models, must be discovered and made available to students in advance. During class, students should have enough time to use resources and think critically. They should also be given enough time to thoroughly investigate the problem.

6. **Increment Oriented Development Approach**:

The artefact to be created should be viewed as a dynamic network of elements, with elements and linkages being created, updated, changed, upgraded, and connected with each increment to provide additional or more complex functionality. The architecture of the finished artefact as a result of project operations should evolve over time, sometimes incorporating iterations [9]. In the early days of EE, it was preferable to have a well-planned and well-structured ladder of increases and revisions. As students become more familiar with engineering concepts and project-based learning, the format may become more adaptable in later years. Previously, theoretical models for increasing the difficulty of student work were documented for educating a few computer science classes, such as object-oriented programming languages, database administration, software engineering, and so on.

7. **Repeated use of diagrammatic representations for generic problem solving:**

A few visual strategies for general problem solving must be used on a regular basis for problem analysis and solution creation. All these diagrams are examples of visualisations and flow charts. They also show how things are put together, how they work together and how they fail, and so on.

8. **Briefing and Debriefing**:

A good presentation must be organised "to set the scene" for each programme, activity, and session. The project scope may be vague to allow students to conduct additional research, consider the problem, and come to an agreement as a group on the activities, direction, and results they want to achieve. In the task briefs, each task must be linked to the intended learning goals and portions of the planned curriculum. The session briefs in the early days of EE should be more targeted, with the goal of connecting the tasks to specific academic topics and their other applications [10]. A link to the relevant learning materials should be included in session summaries. Each session, activity, or project should end with a detailed debriefing that reinforces important learning in knowledge, skills, and mindset.

9. **Work cycles with ongoing critique including reflection:**

Projects should provide time for students to think extensively about their work and how it links to the bigger themes outlined in the learning goals and syllabus. Project work is organised in such a way that there are periods of work and modification, as well as enough time to finish them, allowing for regular debriefing and reflection. Relevant in-class conversations, diary entries, or even follow-up inquiries regarding what students have learned are examples of these. Learners should be exposed to comments on their work regularly and with specific correction recommendations.

10. **Rigor:**

When students are given the opportunity to grapple with a problem before receiving prescriptive suggestions or answers, their rigour improves. Other indicators of rigour include asking students to discuss or defend their reasoning; giving them opportunities to summarise, synthesise, and generalise; comparing and contrasting alternative answers, solutions, and perspectives; and pushing them to apply their knowledge in new contexts.

11. **Logbook:**

Pupils should be urged to keep a logbook for each project in which they may record their preliminary notes, ideas, and design choices. During project meetings, they should keep track of their learning assessments, including self- and team-member assessments [11]. Instructors should review the logbooks, and students should get comments at certain points during the project.

12. **Guidance and Scaffolding:**

To promote deep learning, the teaching method employs a well-planned framework of tasks and gradual learning. A learning scaffold is any strategy or resource that helps a student "complete more difficult tasks than they would otherwise be capable of doing on their own." Pupils should be scaffolded in their learning environments by reducing the complexity of activities while maintaining the essential features. One of the most important aspects of scaffolding is that it must be tailored to the student's current level of understanding. Interactions between students and teachers are common examples, as are practise worksheets, peer counselling, leading questions, job aids, project templates, and so on [12]. A teacher must evaluate a student's skill level or topic understanding on a regular basis in order to tailor a scaffold to that student's needs. Scaffolding should gradually disappear as students are taught to use their new knowledge or abilities independently. The first year, in comparison to subsequent years, necessitates more assistance and organisation.

13. Project Based assessment:

Every programme must include formative and summative assessments. All evaluations should be project-related and follow the primary phases of the design procedure. Summative and formative evaluations should be included in each project. Rubrics for grading design work should include explicit criteria for assigning points. As a result, rather than being overly prescriptive, they should be used as recommendations. Students must be able to see the rubrics and comprehend what is expected of them [13]. In evaluations, a variety of possible solutions must be considered, with the most important factors being suitability to the problem's sense, how well the issue has been explored, comprehended, and resolved, the clarification of the problem formulation, whether the optimal solution has been adequately investigated, and how innovative and creative the remedy is weighed in. It must also evaluate each student's intellectual understanding of the theoretical principles at work. While doing this, it is important to check each student's understanding of the main ideas.

While the PBL approach to EE is a great way to move forward, a superficial application that doesn't include enough knowledge, skilled teachers, curriculum changes, appropriate evaluation, and other factors could backfire.

3. Project based learning in Engineering

The importance of practical integration of theoretical, originality, and invention as fundamental problem-solving abilities is clearly emphasised by research and emerging trends in EE. In the last decade, the world has changed dramatically, and fundamental shifts such as globalisation, technological advancements, interconnectivity, and information accessibility have influenced how current and future generations of children learn. It is difficult for educators to integrate new content into a comprehensive curriculum in a reasonable manner. For a long time, EE was primarily focused on various types of knowledge, but professional industry organisations have recently highlighted a significant shift in emphasis to incorporate more design theory and professional practise features [14]. According to industry executives, engineering graduates must be able to think critically, analyse problems, devise novel solutions, and communicate effectively. According to the Institution of Professional Engineers of New Zealand, "there is a need for expert engineering graduates who are "rounded" and not just technical boffins." "Several of the current graduates lack strong "soft" skills."

Graduates entering industry have mostly theoretical technical knowledge, and businesses must spend a lot of money to bridge the knowledge gap between concepts taught in school and codified information used in industry. Students should learn higher-order thinking skills such as analysis, synthesis, and evaluation, according to the "US Accreditation Board for Engineering and Technology (ABET)" [15]. Students have expressed dissatisfaction with the relevance of their education to real-world situations. As a result, there is an urgent need to change the way students in the twenty-first century are taught and prepared for their future careers. PBL is a tried-and-true method for dealing with some of these issues and requirements. Project-based learning is a broad method of teaching and learning in which students investigate real-world issues. While professors provide guidance to students throughout their project work, students become effective learners and participate in hands-on activities [16]. As a result, project-based learning and teaching require a shift in perspective and role for both learners and lecturers. This strategy, according to the author and her colleagues, increases student motivation by allowing students to apply their theoretical concepts in an interactive environment where they can debate topics with one another and with staff. Students learn to investigate and identify the issue, investigate the best solution among multiple solutions, and iterate and refine their ideas to arrive at a suitable solution that meets the goals. Students progress through the core problem-solving abilities, beginning with basic applications and progressing to more difficult problems [17]. Based on a review of the research, experience with project-based education, and feedback from employers, staff, and students, the following sections make a number of specific recommendations. The best practises and project selection process described in this paper are applicable to a wide range of engineering fields and can be used in most areas of the curriculum.

4. Challenges of Transitioning to PBL Courses

Humans encountered a number of challenges when attempting to implement PBL exercises. Such activities consume a lot of resources, both in terms of faculty time and in terms of detail. Faculty time is in short supply, particularly during the conceptual and first-time implementation phases. For effective implementation and the development of a cooperative faculty team atmosphere, regular exchange of ideas, frequent discussion of techniques and assignments, and the presence of all participating faculty at the majority of project meetings are required. Multiplexing daily activities necessitates the involvement of at least two full-time faculty members [18]. Because the majority of the work is done in groups, it is difficult to assess the situation on an individual basis. Another issue is striking the right balance between the breadth and depth of knowledge required by our students to succeed. Because there has been a rise in business collaborations and donations to PBL initiatives, it may be hard to pay for the projects.

Maintaining the diverse equipment required to complete the projects is also difficult, but we have discovered that using academic staff such as teaching assistants is the most effective method. It gives our graduate students the opportunity to put their project management skills to the test. As part of the PBL process, students must be particularly self-directed in their education and take "ownership" of their education [19]. Confident students can do it, but many students don't know where to look for information or how to distil it down to the concepts needed to solve problems. The most important task, perhaps, is to develop strategies for students to organise, synthesise, and assimilate selected material into their body of knowledge. This process includes locating relevant information sources and tools, such as books, technical publications, review articles, patents, encyclopaedias, handbooks, and databases, as well as determining the appropriate amount and depth of data.It is also critical to select tasks that do not create an overly complicated learning environment [20]. If too many concepts must be learned at once, students may become irritated, diluting the learning process. Projects should be based on solvable problems. Students must also recognise the significance of the issue. If the assignment isn't "interesting," students won't put in the effort to come up with a solution. It's difficult to come up with tasks that pique the interest and enthusiasm of the entire class.

5. Conclusion

This article stresses the importance of incorporating real engineering design methodologies into projects as well as understanding engineering fundamentals. The fundamental issues that faculty face as they work to reform undergraduate EE to incorporate more project-based learning techniques are also addressed. Important criteria for selecting appropriate projects are investigated, as are the critical abilities that can be gained through project-based learning. Some of the best practises, assessments, and examples offered here may be of interest to advanced engineering academics and anyone wishing to provide enhanced learning opportunities to tertiary students.

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