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Impact of Early PBL Course on Final-Year Engineering Project Work

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Abstract

Context

Conventional teaching methods mostly rely on teacher centric approach and doesn't provide interdisciplinary knowledge, with that practice it is difficult for students to survive in the corporate world. In this paper a study on comparison of engineering projects completed with and without project-based learning knowledge has been done by collecting the feedback from passed out engineering students.

Purpose or Goal

To prove the importance of mechatronic skills and project management knowledge in developing quality engineering projects during the final year.

Methods

In this paper a semi structured qualitative analysis is attempted to assess the quality of final-year project work with and without early project-based learning knowledge. First, we have framed two research questions and 11 interview questions and invited the students to KLE Technological university campus through email. Data collection was done through in-person interviews.

Outcomes

By the end of study, we hypothesized that the skillsets developed by the students who have attended first year engineering exploration course, help them in creating a quality project compared to that of students who did not learn the course. hence, we can say that developing mechatronic skills at the early stage of engineering exploration program will help them on understanding and producing high-quality project work.

Conclusion

This study has proven that PBL has more impact on producing quality projects compared to conventional learning. The interactions amongst the students amply illustrated the demand for project-based learning courses to improve the quality of final-year projects as well as the importance of more such learning during their first year of engineering.

Keywords— Project based learning; Mechanism; programming; Project management.

I. INTRODUCTION

CURRENTLY graduate engineers are facing various industry expectations, including technical competence, problem-solving skills, communication skills, teamwork, adaptability, initiative, professionalism, safety awareness, willingness to learn, industry tools knowledge, time management, and business awareness. Employers expect engineering graduates to have a solid foundation in their field and be able to solve real-world problems. Additionally, they expect graduates to communicate complex technical information clearly, collaborate effectively, and adapt to new technologies and trends. Familiarity with industry-specific software and tools is also crucial, as is time management and understanding the broader business context. Hence it is necessary to train undergraduate students in multidisciplinary skills during the college days.

Traditional learning approaches in engineering face disadvantages such as limited practical application, inadequate problem-solving skills, lack of interdisciplinary integration, limited exposure to modern tools and technologies, insufficient project management skills, fixed curricula, limited soft skills development, slow feedback loop, and lack of real-world constraints. These drawbacks hinder student's ability to effectively manage engineering projects, adapt to industry demands, and address real-world constraints.

To address these issues, educational institutions are embracing experiential and project-based learning approaches, incorporating real-world projects, internships, industry collaborations, and modern teaching methods. By embracing these approaches, students can better prepare for real-world engineering projects and develop the necessary skills for success in the field. Hence it is necessary to understand how training students with multidisciplinary skills at their first semester will help them in future projects. therefore, in this study we have analysed how greatly the project-based learning will impact and enhance the student's performance during their final-year projects work, by comparing two set of students with and without PBL course. The details of literature survey are explained in the next section.

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II. Literature Survey

Research has shown that project-based learning can significantly improve student learning outcomes and engagement in various subjects. In research on the introduction of a project-based learning strategy in an undergraduate course on new product development, Zancul et al., (2017) focused on this issue. Their study sought to assess how well this pedagogical strategy improved the learning results and engagement of students. The results of this study showed that adding project-based learning strategies to the curriculum significantly improved the course. In the context of introductory engineering design courses, Carpenter et al., (2016) investigated the application of project-based learning. Their research emphasized this strategy's beneficial effects on student engagement. The study revealed that by incorporating real-world projects into the curriculum, students were more motivated and actively involved in their learning. This essay highlights the potential advantages of project-based instruction in introductory engineering courses. In specifically, in the area of requirement engineering, Daun et al., (2016) discussed their experiences with project-based learning in academic settings. Their research provided understandings into how real-world business examples might be incorporated into the classroom setting to improve student comprehension and implementation of course content. This experience report provides insightful advice on how to effectively apply project-based learning in engineering education. In an academic engineering course, Frank et al., (2003) investigation focused on the application of the project-based learning strategy. Their in-depth analysis covered not only the theoretical underpinnings but also the practical elements of incorporating project-based learning into the curriculum. In order to adapt project-based learning for engineering instruction, a core grasp of the concept is provided in this work. Uziak (2016) looked into the use of a project-based learning strategy inside an engineering programme. The study examined the beneficial effects of this educational strategy, highlighting improved learning opportunities and higher levels of student involvement. The paper discusses the potential advantages of project-based learning for both educators and students studying engineering. In a technical institution in India, Patil et al., (2022) looked into the learning preferences of first-year undergraduate engineering majors. Although not specifically about project-based learning, the information in this paper about the various learning styles of engineering students might help teachers when creating and implementing project-based learning activities. Multimodal machine learning was used by Joshi et al.,(2022) to predict student's performance. Although this research is not specifically relevant to project-based learning, it may provide useful insights into evaluating the outcomes and efficacy of project-based learning strategies. The essential elements of project-based learning in K–12 scientific education was examined by Markula & Aksela (2022) The principles and traits presented in this work may still be applicable to understanding how project-based learning can be implemented successfully in engineering education, despite the fact that the educational level is different. It offers a more comprehensive viewpoint on teaching methods. Project-based learning facilitates an integrated experience, as mentioned by Shet et al., (2015) This essay focuses on the all-encompassing advantages of this teaching strategy, such as how information and abilities from other fields are integrated. It helps us comprehend how project-based learning in engineering education can change the way students learn. The idea of developing an integrated learning experience within curriculum threads through mini-projects was first proposed by Mudenagudi et al., (2015) This strategy entails including smaller-scale projects in the curriculum, which is beneficial for engineering programmes in particular. The article presents suggestions for how project-based learning can be modified to fit various course formats. Mini-projects were described as a transformative teaching and learning process by Jadhav & Patil (2015) This study investigates an alternative viewpoint on incorporating real-world projects into engineering education, which, while comparable to project-based learning but may provide instructors with a variety of student engagement tactics. A study on troubleshooting within an online circuit modeling platform was carried out by Humbi et al., (2022) as a component of a blended project-based learning course. The troubleshooting procedure used by first-year undergraduate students is the specific topic of the paper. This study sheds light on the difficulties and teaching opportunities related to practical engineering activities. A freshman engineering course's design and evolution was discussed by Baligar et al., (2019) as part of their shared collaborative experience. Although not directly relevant to project-based learning, this study provides insightful information about curriculum development and cutting-edge instructional strategies. Teachers can incorporate project-based learning components by learning about the design and development of engineering courses.

According to Prince, M. J., & Felder, R. M. (2006) Science and engineering courses are traditionally taught by starting with lectures on fundamental concepts and having students apply what they have learned. This research, however, examines other methods that start with observations, questions, issues, or case studies, such as inquiry learning, problem-based learning, and discovery learning. With varied degrees of instructor assistance, these approaches enable students to gain knowledge and skills in context, encouraging more in-depth study and critical thinking. There is compelling evidence that supports these inductive approaches above conventional deductive teaching, despite the fact that support for them differs. Empirical studies and brain research support the use of inductive methods in

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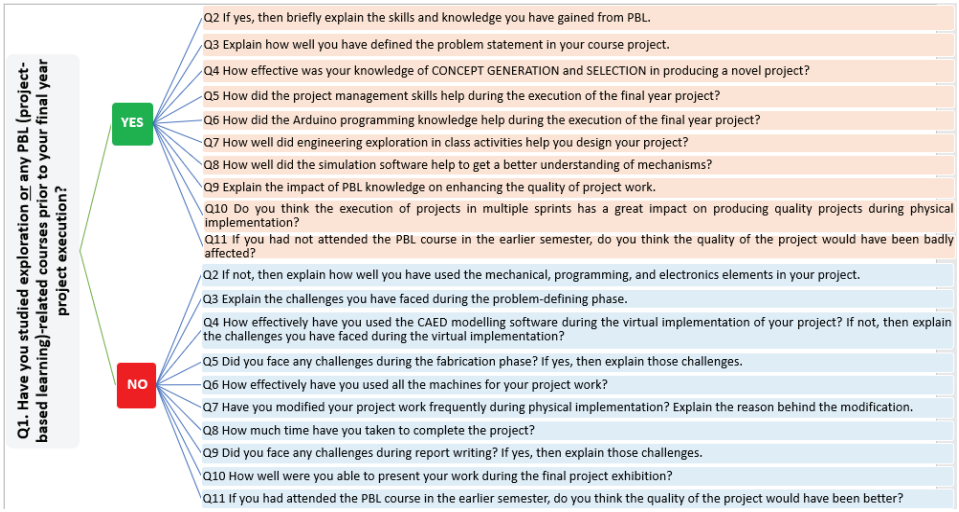

Fig. 1. Interview questions

education, which are consistent with ideas such as constructivism. They support students in acquiring critical thinking and self-directed learning abilities and promote meaningful learning as opposed to mindless memorizing. But using an inductive technique alone does not ensure improved learning outcomes. Student resistance and discontent might result from poor implementation. Students may find it difficult to take on more responsibility for their education, which could result in subpar performance and unfavorable reviews. In order to use inductive teaching effectively, teachers need to get familiar with best practices, such as giving students enough support at first and reducing it gradually as they gain confidence. Teachers need to prepare for and use tactics to deal with opposition from students.

When taken as a whole, these publications present a substantial and varied body of research on project-based learning in engineering education. They offer important insights into its application, effects, and possible advantages for both students and educators. Best practices in engineering pedagogy can be informed by these findings and additional study can be guided by them.

To address all the above discussed issues, we conducted a semi structured qualitative analysis by conducting in person student's interview at our college campus. To collect the student's feedback, we have created two research questions, which are as follows.

R1: What challenges did students encounter when working on projects without having taken a PBL course?

R2: How did PBL training in the early stages of engineering assist students to deal with challenges while working on their upcoming projects?

The first research question will aid in obtaining the perspectives of students who have not previously taken any PBL courses before the execution of final-year engineering projects. Second question will help to get the feedback of students those who have completed engineering exploration or any other PBL course prior to final-year project execution.

About the engineering exploration course that was made available to first-year students at KLE Technical University Hubli in 2015. Students are learning project management and mechatronics in this course.

III. Methodology

The significance of how mechatronic and project management information obtained during the first-year exploration course will help in generating a quality engineering project in the final-year is investigated using a semi structured qualitative analysis method. The study has been conducted at KLE Technological university for the graduated students who have finished their degrees in engineering during the last four years. The sampling and data collection process is as follows.

A. Sampling Process

We have selected two types of participants for our study. Population A consists of graduated engineering students who have learned engineering exploration course, which is introduced during their first-year academics and they have gained the mechatronic and project management skills.

Population B consists of students who were taught using traditional methods without having any prior experience to engineering exploration or any PBL course.

Population A has the sample size of 5 students and population B has the sample size of 6 students.

B. Data Collection Process

We have collected the data from the graduated engineering students by informing through email. The data collection mode was through in-person one to one interview at our KLE Technological university campus. The following techniques

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were used to gather data for this study:

1) Informed consent

Prior to participation, informed consent paperwork outlining the study's goals, data collection techniques, and participant's rights will be given to all chosen students. They will have the choice to accept or reject the offer to participate.

2) Voice recording process

During the interview process we have asked the questions and recorded the students feedback using live transcriber application software. This software will help to convert voice to word.

3) Privacy and considerations

Data was coded anonymously and participant identities were kept private. Access to personally identifiable data was only be available to the research team.

4) Interview questions

For two Research questions as mentioned in the methodology section, we framed 11interview questions each to both the Population A and B, so that students will be able to give detailed insight of their experience while conducting the final-year projects w.r.t Problem definition, concept generation, concept selection, Virtual implementation, physical implementation, report writing. These questions are framed in such way that students will give their genuine feedback without any manipulations. block diagram of all 11 interview questions is depicted in Fig. 1.

C. Data Analysis

We have used MAXQDA software to analyze the data collected from the students. The detailed analysis of students without early PBL education are done and presented in TABLE I by mentioning questions, themes and quotations. We have coded the student response using the pseudonyms a1, b1…… v1.The detailed analysis of students with early PBL education are done and presented in TABLE II by mentioning questions, themes and quotations. We have coded the student response using the pseudonyms a2, b2…… v2.

IV. Results and Discussion

The findings of our qualitative study on the influence of early Problem-Based Learning (PBL) knowledge on the quality of final-year projects are presented in this section. The analysis included looking at the student's feedback. Our primary goal was to identify patterns, themes, and trends regarding how early PBL exposure affected project outcomes. The detailed results of this qualitative study are as follows.

A. Improved Problem Definition and Identification

According to our data, students who were exposed to PBL early on showed a more advanced comprehension of problem description and identification in their final-year projects. They were better at identifying the fundamental problems and situating their work within a wider context. They were able to develop clear project objectives and research questions thanks to their early understanding, which ultimately resulted in more focused and pertinent projects.

B. Enhanced Analytical and Critical Thinking

Students that participated in PBL in their early years of instruction demonstrated improved analytical and critical thinking abilities. They were better able to evaluate existing material critically and synthesize it, which allowed them to create initiatives with more thorough theoretical underpinnings. This resulted in more rigorous investigation and analysis, which had a favourable effect on the general caliber of their capstone projects.

C. Increased Communication and Collaboration

PBL encourages a collaborative learning environment, and students who engaged in PBL activities from the start of their academic careers improved their ability to communicate and work in teams. During the final-year project phase, this was demonstrated by their capacity to work productively with their classmates, faculty advisors, and external stakeholders. The successful completion of interdisciplinary initiatives and the integration of many views that enriched the project outputs were made possible by improved teamwork.

D. Increased Creativity and Innovation

PBL early on encouraged student's inventiveness and creativity. In their final-year projects, they were more likely to investigate unusual ways and solutions, leading to original and cutting-edge contributions to their respective fields. This creative problem-solving was especially clear in projects that dealt with complicated, real-world issues, demonstrating the beneficial effects of early PBL knowledge on the cultivation of innovative problem-solving skills.

E. Increased Project Management Capabilities

Early PBL experience students showed exceptional project management abilities. Their project planning and execution, deadline adherence, and resource management were all more well-organized. The timely completion of excellent final-year projects was directly attributed to the enhanced project management.

In summary, our qualitative analysis offers strong evidence in favour of the beneficial influence of early PBL knowledge on the caliber of senior project outcomes. The results indicate that early exposure to PBL improves problem definition and identification of problems, analytical and critical thinking skills, teamwork and communication skills, creativity, and project management abilities, all of which contribute to the overall excellence of final-year projects. These findings highlight the value of using PBL at an early age in order to support student's academic and professional development.

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TABLE I
SUMMARY OF STUDENTS ANALYSIS WITHOUT EARLY PBL KNOWLEDGE

Questions	Themes	Quotations
Q1: Have you studied exploration or any PBL (project-based learning)-related courses prior to your final-year project execution?	Lack of PBL Training Authors	"I had to rely solely on my mechanical, programming, and electronics knowledge because I had no prior PBL training."a1 "Without PBL, I had to figure out how to integrate mechanical, programming, and electronics elements on my own."b1
Q2: If not, then explain how well you have used the mechanical, programming, and electronics elements in your project. Keywords	Utilization of Knowledge	"I had to effectively utilize my existing knowledge to make up for the lack of PBL training."c1 "I had to apply what I learned in my coursework to make sure that my project included mechanical, programming, and electronics elements."d1
Q3: Explain the challenges you have faced during the problem-defining phase.	Problem Formulation Challenges 3	"Defining the problem was a major challenge, as I lacked structured guidance that PBL could have provided."e1 "Without PBL, it was difficult to gather client requirements and convert them into a clear problem statement."f1
Q4: How effectively have you used the CAED modelling software during the virtual implementation of your project? If not, then explain the challenges you have faced during the virtual implementation?	Challenges in Virtual Implementation	"Without prior PBL training, I had trouble using CAED modelling software for virtual implementation. "g1 "Virtual implementation was difficult without PBL because I had to use difficult software tools alone."h1
Q5: Did you face any challenges during the fabrication phase? If yes, then explain those challenges.	Challenges in Fabrication Phase	"Fabrication presented a number of challenges, particularly with regard to sourcing materials and coordinating the assembly process."i1 "I had trouble fabricating the project components because there was no PBL-based guidance."j1
Q6: How effectively have you used all the machines for your project work?	Challenges in Machine Utilization	"Without PBL, I found it difficult to use machines for my project work because I had little experience with them."k1 "Machine utilization was difficult because I had to pick up new skills on the job and get used to using different equipment."l1
Q7: Have you modified your project work frequently during physical implementation? Explain the reason behind the modification.	Frequent Project Modifications	"I found myself frequently changing the project because, at first, I didn't have clarity on certain aspects due to the absence of PBL guidance."m1 "Without PBL, I encountered unforeseen issues during physical implementation and had to make several modifications. n1
Q8 How much time have you taken to complete the project?	Project Completion Time	"The project took longer than expected to complete because I had to spend extra time troubleshooting and addressing challenges."o1 "It took me longer to complete the project without PBL because of the learning curve and overcoming challenges independently."p1
Q9 Did you face any challenges during report writing? If yes, then explain those challenges.	Challenges in Report Writing	"Without PBL, I had difficulty structuring and effectively presenting my project findings in the report."q1 "Without PBL, I had difficulty structuring and effectively presenting my project findings in the report."r1
Q10 How well were you able to present your work during the final project exhibition?	Project Presentation	"Without PBL experience, I found it a little difficult to articulate and present my work effectively during the final project exhibition."s1 "I think I could have improved my presentation skills if I had PBL-based training earlier."t1
Q11 If you had attended the PBL course in the earlier semester, do you think the quality of the project would have been better?	Hypothetical Impact of PBL Training	"I believe that if I had taken PBL courses earlier, the quality of my project would have been significantly better."u1 "PBL training would have given me useful skills and direction that could have improved the overall quality of my project"v1

TABLE II
SUMMARY OF STUDENTS ANALYSIS WITH EARLY PBL KNOWLEDGE

Questions	Themes	Quotations
Q1: Have you studied exploration or any PBL (project-based learning)-related courses before executing your final-year project?	PBL Education	"Yes, I had the chance to take courses related to PBL, which greatly enhanced my project experience."a2 "I benefited from prior PBL training, which was essential in the development of my final-year project."b2
Q2: If yes, then briefly explain the skills and knowledge you have gained from PBL.	Skills and Knowledge Acquired	"I developed my problem-solving, teamwork, and project management skills through PBL."c2 "PBL taught me how to programme Arduino, design mechanisms, and use simulation tools, all of which were extremely helpful for my project."d2
Q3: Explain how well you have defined the problem statement in your course project.	Effective Problem Statement Definition	"PBL training gave me the abilities to communicate with clients, collect requirements, and formulate a precise problem statement."e2 "By utilizing PBL principles of client interaction and need analysis, I was able to define the problem statement effectively."f2
Q4: How effective was your knowledge of CONCEPT GENERATION and SELECTION in producing a novel project?	Facilitating Concept Generation and Selection	"PBL emphasized methods such as concept scoring and brainstorming, which significantly aided in generating and choosing innovative project concepts,"g2 "The concept generation and selection methods used by PBL helped to generate creative and workable project ideas."h2
Q5: How did the project management skills help during the execution of the final-year project?	Project Management Skills	"PBL gave me the project management skills I needed to successfully manage my final-year project's resources, time, and team dynamics."i2 "I credit the project management abilities I developed through PBL training for the efficient execution of my project."j2
Q6: How did the Arduino programming knowledge help during the execution of the final-year project?	Benefits of Arduino Programming Knowledge	"The incorporation of electronic components in my final-year project was greatly facilitated by my proficiency in Arduino programming, gained through PBL."k2 "My project's functionality was improved by the ease with which I was able to incorporate sensors and actuators thanks to PBL's focus on Arduino programming."l2
Q7: How well did engineering exploration in class activities help you design your project?	In class activities	"Engineering exploration activities in PBL courses gave me real-world experience and improved my ability to design complex projects," m2 "Engineering Exploration's hands-on activities helped me better understand mechanisms and apply that knowledge to my final-year project,"n2
Q8: How well did the simulation software help to get a better understanding of mechanisms?	Benefits of Simulation Software	"The introduction of simulation software in PBL training gave me a clear understanding of mechanisms and allowed me to fine-tune the design of my project."o2 "Using simulation software was a key step in my project's development process, ensuring better clarity and precision in mechanisms."p2
Q9: Explain the impact of PBL knowledge on enhancing the quality of project work.	Enhancing Project Quality	"PBL knowledge elevated the quality of my project by allowing me to deliver a more refined solution, make informed decisions, and choose the right components."q2 "The thoroughness of my project execution and the final output show the impact of PBL knowledge on project quality."r2
Q10: Do you think the execution of projects in multiple sprints has a great impact on producing quality projects during physical implementation?	Benefits of Multiple Sprints	"Using PBL lessons learned, the project was implemented in multiple sprints, allowing for better control, problem-solving, and overall higher project quality during physical implementation."s2 "PBL's approach of carrying out projects in multiple sprints played a crucial role in ensuring that the project components integrated seamlessly."t2
Q11: If you had not attended the PBL course in the earlier semester, do you think the quality of the project would have been badly affected?	Hypothetical Effects of PBL Training Absence	"I feel that my project's quality would have suffered without PBL training, especially in terms of problem definition, concept selection, and project management."u2 "The lack of PBL training would have had a negative impact on the overall quality and execution efficiency of my project."v2

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V. Conclusion

By the end of study, we came to conclude that the skillsets developed by the students who have attended first year engineering exploration course, help them in creating a quality project compared to that of students who did not learn the course. hence, we can say that developing mechatronic skills at the early stage of engineering exploration program will help them on understanding and producing high-quality project work.

Hence this study has proven that PBL has more impact to enhance the student's abilities in areas like reading technical publications, creating, developing, and simulating the mechanisms, organizing their work, effective communication and presentation, self-assurance, and teamwork.

Future Implications

To enhance the qualitative analysis, we propose expanding the participant pool to encompass a more diverse range of students from various institutions and backgrounds. An in-depth look at skill development would be possible with a longitudinal study that follows students from their initial exposure to PBL to their final-year projects. The effects can be directly compared and isolated by including a control group that hasn't had any early PBL exposure. Furthermore, adding quantitative data collected through surveys and standardized tests will support the qualitative findings obtained. Focusing on experiences and viewpoints, in-depth interviews and reviews by external experts should be more systematic. The analysis will gain depth and richness by taking socioeconomic and cultural issues into account and by creating a feedback loop with students.

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