Enhancing Project Outcomes in First-Year PBL Courses through Increased Teaching Sessions

Marshed Mohamed[1], **Livinus Nweke**[2]

[1]Department of Electronic Systems, Norwegian University of Science and Technology, Norway
[2]Department of Computing, Noroff University College, Norway

Abstract

The quality of student projects in a first-year Computer Architecture course has long been a concern, with many submissions reflecting insufficient mastery of foundational concepts and a lack of confidence to tackle challenging tasks. These issues are compounded by students' limited base knowledge and undeveloped self-learning abilities, which are critical for success in project-based learning (PBL). To address these challenges, the course's teaching sessions were doubled from six to twelve, while assignments were redesigned to integrate knowledge from multiple sessions. This intervention aimed to provide a stronger foundation, foster self-learning, and enhance project outcomes. The results showed significant improvements in student performance and confidence. Project grades increased substantially, with more than 50% of students achieving a grade of B or higher in 2024, compared to only 25% in 2023. Students reported greater confidence in undertaking challenging projects, with over 80% attributing this to the enhanced teaching sessions. Self-learning also improved, as 84% of students independently explored advanced topics like sensor integration and communication protocols to complete more sophisticated projects. Despite the reduction in project implementation time from 15 to 6 weeks, the projects demonstrated higher complexity and quality, underscoring the critical role of foundational instruction. This study highlights the importance of integrating structured teaching sessions with guided assignments to bolster foundational knowledge and promote self-learning. The findings provide actionable insights for improving PBL frameworks, contributing to enhanced educational practices in engineering and related disciplines.

Keywords: *Project-based learning; Foundational instruction; Teaching sessions; Self-directed learning; Engineering education.*

1. Introduction

Project-based learning (PBL) has become an integral part of engineering education as it has been recognized for its effectiveness in enhancing student engagement and bridging the gap between theoretical knowledge and practical application. Recent studies have demonstrated that PBL enables students to cultivate essential technical skills as well as fosters critical thinking, problem-solving abilities, and collaborative learning [1–4]. In the context of engineering education, PBL offers practical means for students to understand abstract concepts by allowing them to apply them in tangible ways [5–7]. This hands-on approach not only enhances understanding but also prepares students for the dynamic challenges of the engineering profession.

Despite the benefits of PBL, first-year students often encounter significant challenges when engaging in project-based assignments within the Computer Architecture course. Their limited foundational knowledge and inexperience can make the transition from structured learning environments to independent project work particularly daunting [8]. Many students exhibit a lack of confidence in selecting appropriately challenging tasks and possess insufficient skills to effectively tackle complex problems [9–12]. This is further exacerbated by the steep learning curve associated with Computer Architecture concepts, which necessitate a solid grasp of both hardware and software principles. Consequently, the quality of submitted projects has been consistently subpar, leading to overall poor performance in project evaluations.

The persistent issue of low-quality project submissions highlights a critical problem in the current educational approach. Specifically, the inadequate number of teaching sessions which was originally limited to six teaching sessions in our case study appears insufficient for first-year students who are still adapting to university-level expectations and learning methodologies. Limited instructional time constraints students' ability to fully comprehend course material, develop essential skills, and build the confidence required to engage deeply with challenging projects [13]. This gap not only adversely affects their academic outcomes but also impedes their development as self-directed learners, a crucial attribute in the rapidly evolving field of computer engineering.

In response to these challenges, the purpose of this study is to evaluate the impact of increasing the number of teaching sessions from six to twelve in a first-year Computer Architecture course. The rationale behind this intervention is to provide students with additional instructional time to reinforce their understanding of fundamental concepts, thereby enhancing their capacity to apply this knowledge in project settings. By extending the teaching sessions, we aim to offer more opportunities for guided learning, hands-on practice, and personalized feedback which are all essential for developing competence and confidence in novice learners.

The objectives of this study are threefold. First, we aim to enhance students' knowledge base by covering more content in greater depth and providing additional resources for learning. Second, we seek to improve students' self-learning abilities by equipping them with strategies and tools for independent study, critical thinking, and problem-solving. Third, we intend to improve project outcomes by enabling students to undertake more ambitious projects with a higher likelihood of success, thereby fostering a sense of achievement and motivation.
The significance of this study extends beyond the immediate context of the Computer Architecture course. By examining the effects of increased instructional time on student performance and learning experiences, the findings have the potential to inform teaching practices in similar educational settings. Educators and curriculum designers can leverage these insights to optimize course structures, allocate resources more effectively, and implement strategies that support student learning and engagement. Ultimately, this study contributes to the broader discourse on enhancing engineering education by identifying practical solutions to common pedagogical challenges.
The rest of this article is organized as follows. Section 2 presents the methodology that guided this study. Section 3 discusses the results obtained while 4 concludes the paper.

2. Methodology

This section outlines the research design, the course and participants, the course structure, the intervention, and the evaluation methods.

2.1 Research Design

The study employed a mixed-methods comparative research design to evaluate the impact of increasing teaching sessions from six to twelve on student outcomes in a first-year Computer Architecture course. The mixed-methods approach integrates both quantitative and qualitative data to provide a comprehensive understanding of how the intervention affects students' knowledge acquisition, self-learning abilities, and project performance. On the other hand, the comparative aspect of the study involves analyzing and contrasting data collected from two distinct cohorts of students: one that experienced the original six teaching sessions (the control group) and another that participated in the enhanced twelve teaching sessions (the experimental group). By comparing these groups, the study aims to isolate the effects of the increased instructional time on various learning outcomes.

2.2 The Course and Participants

The course used in the study was Computer Architecture, a five-credit points course taken by first-year students in Bachelor of Engineering – Telematics, at the Norwegian Defense University College, Norway. The course aims to provide students with an understanding of the important building blocks of a computer and the connection between these building blocks (hardware) and the software that controls them. The study involved first-year students enrolled in the Computer Architecture course over two consecutive academic years. The control group consists of students from the year before the intervention, while the experimental group includes students from the year when the increased teaching sessions were implemented. Both cohorts consist of approximately the same number of students (e.g., 40 students per cohort) to ensure comparability.

2.3 The Course Structure

Over the years, the fundamental knowledge of the course has been provided through six teaching sessions, each accompanied by an assignment designed to reinforce the concepts covered (one assignment per teaching session). This structure aimed to equip students with a foundational platform for self-learning and enable them to deliver challenging projects for evaluation. The topics covered in each session, along with their accompanying assignments, are summarized in Table 1.

Table 1. Teaching sessions and their accompanied assignments in 2023

Teaching Session	Topic	Assignment
1	Introduction to Microcontrollers	1
2	Digital Output	2
3	Digital Input	3
4	Interrupts, Timers, and LCD	4
5	Analog-to-Digital Conversion	5
6	Serial I/O	6

While the topics covered are essential, the time allocated to them appears insufficient to address the critical details comprehensively. For instance, teaching session 4 covers interrupts, timers, and LCDs. Each of these topics is extensive and significant enough to warrant its own dedicated session. Similarly, Analog-to-Digital Conversion (ADC), introduced in session 5, could benefit from being

expanded into two teaching sessions. ADC is a fundamental concept in which measurable phenomena typically analog in nature are captured through transducers (sensors) and converted into digital signals for processing by digital devices. Expanding this topic would allow students to develop a deeper understanding of this crucial process.
In addition to insufficient time allocation, the current plan omits several important topics. While there is a session on digital output, the equally important concept of analog output is not addressed. For example, Pulse-Width Modulation (PWM) is an essential technique that enables digital devices to produce outputs resembling natural analog signals, which are more intuitive for users. Including this topic would enhance the curriculum by bridging the gap between digital and analog systems.
Another area that could be expanded is communication protocols. While Serial I/O is covered in session 6, introducing an additional protocol such as I2C would provide students with exposure to more sophisticated and widely used communication systems. This addition would deepen their understanding of the diverse communication protocols available in modern systems.
Lastly, the current plan includes only one session on the integration of microcontrollers with external devices, focusing on LCDs. Introducing an additional example involving other common devices, such as Servo Motors, would enhance students' practical understanding of microcontroller applications. Expanding this area would provide students with broader insights into real-world use cases and improve their ability to design versatile and practical solutions.

2.4 *The Intervention (Proposed Changes)*

The updated content of the teaching sessions and their accompanying assignments (course plan) is summarized in Table 2. This revised course plan was implemented in the spring semester of 2024. While

Table 2. Teaching sessions and their accompanied assignments in 2024

Teaching Session	Topic	Assignment
1	Introduction to Microcontrollers	1
2	Digital Output	
3	Digital Input	2
4	Interrupts	
5	Timers	3
6	Pulse-Width Modulation	
7	Analog-to-Digital Conversion I	4
8	Analog-to-Digital Conversion II	
9	Serial I/O	5
10	I2C	
11	Driving Servo Motors	6
12	LCD	

the number of teaching sessions has doubled compared to the previous plan (Table 1), the number of assignments has remained unchanged. However, the assignments were designed to require knowledge from at least two different teaching sessions. This approach ensures that students not only build their competencies in specific topics but also develop an understanding of how these topics interconnect. The addition of six more teaching sessions reduced the time allocated for the self-selected individual project from fifteen weeks to six weeks. Despite this reduction, the stronger foundation provided by the additional teaching sessions more than compensated for the shortened project duration. The enhanced preparation allowed students to complete more challenging projects within the six weeks, using appropriate methods and demonstrating higher-quality outcomes than before.
Furthermore, during the six-week project period, students were required to consult with the course instructor at three distinct stages of their project. These consultations ensured that the projects met the required level of challenge and quality. This iterative review process not only provided guidance but also fostered a consistent focus on achieving high standards in project implementation.

2.5 *Evaluation Method*

The evaluation of the implemented measures was conducted using two primary methods: the analysis of project evaluation results and feedback collected from students. Significant improvement in project outcomes would serve as the strongest indicator that the implemented changes had a positive impact. However, it is important to acknowledge that several other factors could influence the results, such as the quality of the students, their attitude toward the subject, their understanding of prerequisite courses, and even the workload from other courses. These variables could have a considerable impact on the quality of the projects and, consequently, on their evaluation results. To mitigate the influence of these confounding factors, a long-term observation of results before and after the implementation of the proposed measures should be conducted to establish more robust conclusions.

Student feedback was collected through the reference group and normal course evaluation procedures. Two specific survey questions, asked both before and after the changes were implemented, were particularly insightful in this context:

A. Which learning activities used in the course have given you the greatest learning benefit?
B. To what extent did you experience that the general workload in this subject corresponded to thelearning outcome descriptions and the number of credits?

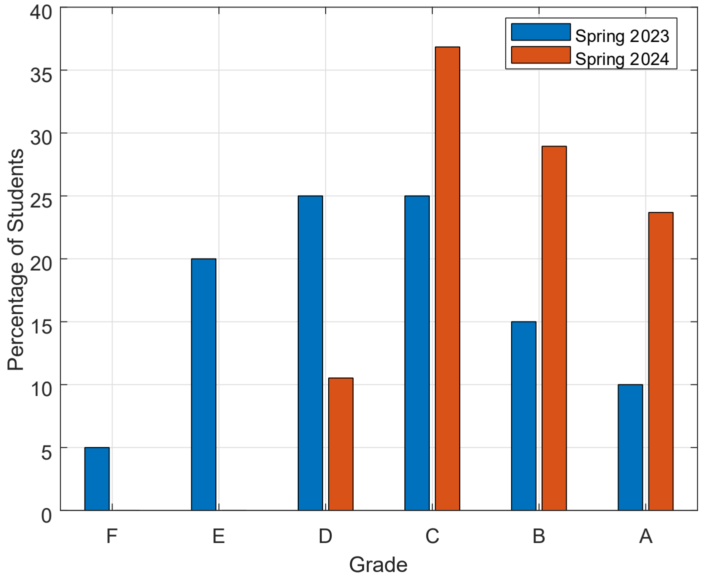

Fig. 1. Comparison of projects' evaluation results between spring 2023 and spring 2024.

The answers to Question A were intended to indicate whether the teaching sessions, along with their accompanying assignments, provided sufficient knowledge to enhance self-learning. Meanwhile, the answers to Question B shed light on how manageable the self-learning process was for students. A negative correlation between these two questions was anticipated; students finding the workload too demanding might report lower benefits from the learning activities.
In addition to the standard questions, the following were added to the survey form used after the implementation of the proposed changes:

C. Did the teaching sessions give you confidence to undertake challenging projects?
D. Did the teaching sessions make it easier to learn on your own?E. During the implementation phase of your project
   (i). Did you self-learn anything new?
   (ii). What did you teach yourself?

These questions aimed to determine whether the teaching sessions provided a sufficient foundation of knowledge to support students' self-learning. They also sought to explore the influence of the sessions and accompanying assignments on the types of projects students chose to undertake.
Students were asked to respond to Questions A, B, C, and D by indicating the extent to which they agreed with the statements, using a five-point scale: "agree to a very large extent," "a large extent," "a medium extent," "a small extent," and "a very small extent." For Question E(i), students answered "yes" or "no," while those who selected "yes" were invited to elaborate on their response to Question E(ii) in their own words.

3. Results

The results obtained from the discussed evaluation methods are presented in this section. The results are divided into project evaluation, survey questions before and after the implemented measures, and additional survey questions.

3.1 Project Evaluation

Significant improvements were observed in the submitted projects after the implementation of the proposed measures, particularly in terms of the challenges addressed by the projects and the methods students used to overcome these challenges. This improvement is reflected in the grades students received during project evaluation. The evaluation for the semester in question (spring 2024) was conducted by the same two examiners as in the previous year (spring 2023), ensuring consistency in grading standards.

A comparison of the results between the two semesters is presented in Fig. 1. While only a quarter of the students achieved a grade of B or higher in 2023, more than half of the students attained these grades in 2024. The improvement is even more pronounced at the lower end of the grade scale, where only 10% of students received a grade of D in 2024, with no students receiving grades lower than D. This is in stark contrast to the results from 2023, where half of the students were graded at D or lower.

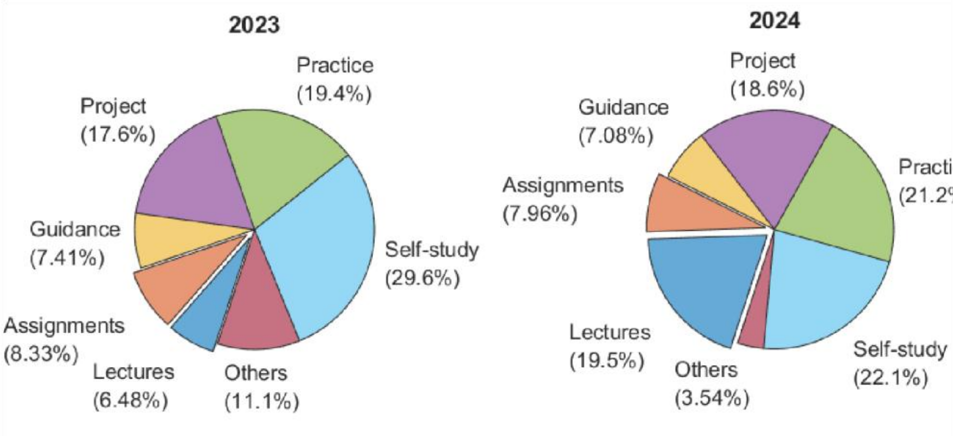

Fig. 2. Summary of the answers to the question “which learning activities used in the course have given you the greatest learning benefit?”

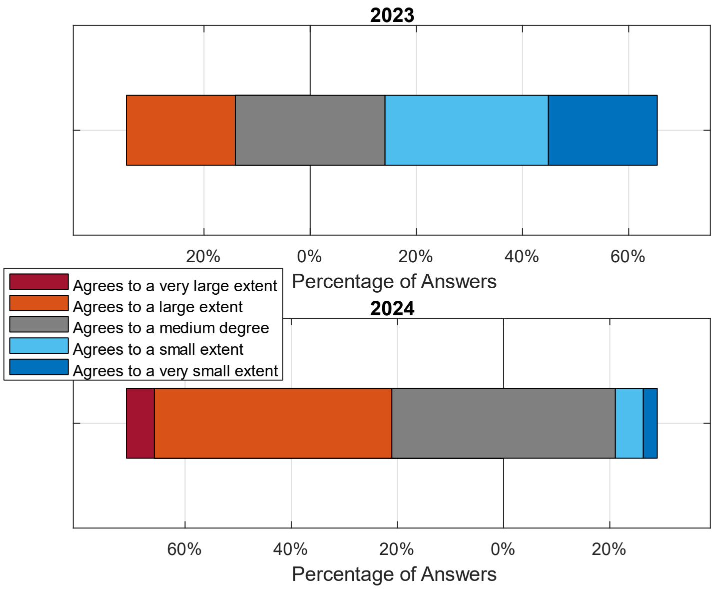

Fig. 3. Summary of the answers to the question “To what extent did you experience that the general workload in this subject has corresponded to the learning outcome descriptions and the number of credits?”

3.2 Comparable Survey Questions

We can further compare the results by analyzing the answers to Questions A, “which learning activities used in the course have given you the greatest learning benefit?” from 2024 and those provided in 2023. As shown in Fig. 2, the percentage of students selecting lectures as the activity that provided them with the greatest learning benefit increased threefold, rising from 6.5% in 2023 to 19.5% in 2024. This significant change suggests that the teaching sessions are now successfully fulfilling their intended purpose of providing fundamental knowledge of the subject.
To evaluate whether the teaching sessions facilitated self-learning and reduced the perceived workload of the course, we compared students’ responses to Question B, “To what extent did you experience that the general workload in this subject has corresponded to the learning outcome descriptions and the number of credits?” from 2023 and 2024. As illustrated in Fig. 3, the percentage of students who considered the workload too heavy decreased by more than half, from 65% in 2023 to 30% in 2024. Notably, self-study continued to be identified by many students (Fig. 2) as the activity that provided the greatest learning benefit. These results imply that the reduced perception of

workload is not due to a decrease in self-learning but rather because students are now engaging in self-learning more efficiently.

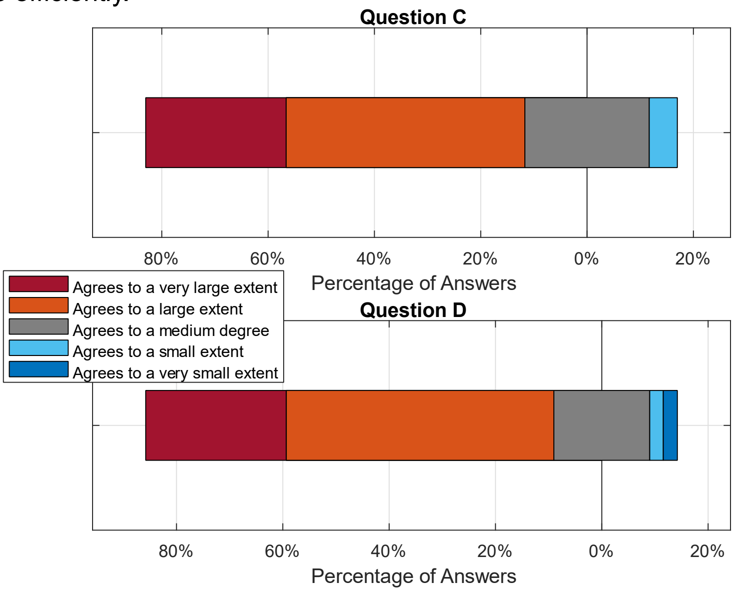

Fig. 4. Summary of the answers to Question C, “Did the teaching sessions give you confidence to undertake challenging projects?”, and Question D, “Did the teaching sessions made it easier to learn on your own?”.

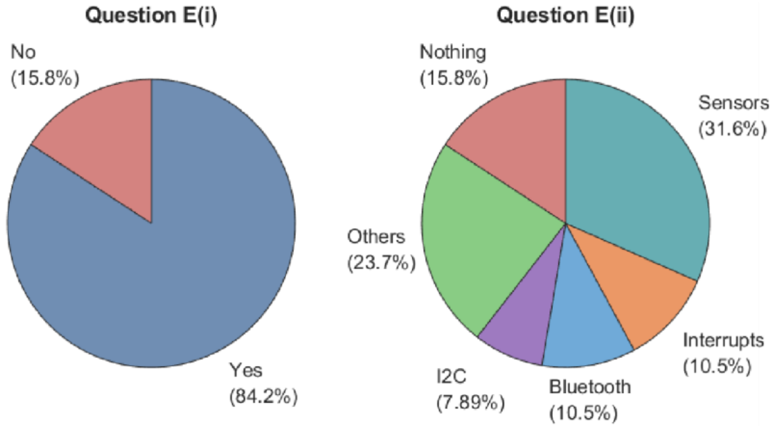

Fig. 5. Summary of the answer to Question E(i) “Did you self-learn anything new during the implementation phase of your project?” and Question E(ii) “What did you teach yourself?”.

3.3 Additional Survey Questions

The students’ responses to the additional questions (Questions C, D, and E) provide even clearer evidence that the implemented changes achieved their intended outcomes. The responses to Question C, “Did the teaching sessions give you confidence to undertake challenging projects?”, and Question D, “Did the teaching sessions made it easier to learn on your own?” are summarized in Fig. 4. The figure shows that over 80% of students believed the teaching sessions significantly contributed to building their confidence to undertake challenging projects, with more than a quarter indicating that the sessions achieved this to a very large extent. Similarly, approximately 85% of students agreed that the teaching sessions provided the fundamental knowledge needed to facilitate self-learning, with more than a quarter stating this was achieved to a very large degree.

Lastly, the responses to Question E(i), “Did you self-learn anything new during the implementation of your project?”, and the topics students self-learned during the project phase are summarized in Fig. 5. Approximately 16% of students indicated that the teaching sessions and accompanying assignments alone were sufficient to complete their projects. However, 84% of students reported learning additional material independently to successfully complete their projects. This latter finding suggests that a significant portion of students had the confidence to undertake more challenging projects that extended beyond the topics covered in the teaching sessions or assignments. Nearly a third of the students (31.6%) learned how to integrate sensors not covered in the teaching sessions with the microcontroller, gaining practical experience in reading and interpreting device datasheets. Communication protocols were another common area of independent learning, with 10.5% of students learning and using the Bluetooth protocol and 7.89% expanding their knowledge of the I2C protocol. Another notable topic was Interrupts, where 10.5% of students deepened their understanding and skills beyond what was taught in the sessions. These findings demonstrate that the teaching sessions, along with their accompanying assignments, effectively covered the fundamental concepts necessary to complete basic projects. Moreover, they provided an excellent foundation for self-learning and built the confidence needed to undertake more complex and challenging projects. This balance between guided instruction and independent exploration underscores the effectiveness of the implemented changes in enhancing both foundational knowledge and students' ability to expand their learning independently.

3.4 Interpretation of the Results

The findings of this study affirm that strengthening fundamental knowledge through increased teaching sessions bolsters student confidence, skill acquisition, and self-directed learning, which are key factors that facilitate better project performance. Recent literature emphasizes that foundational topics must be thoroughly covered in engineering education, especially in project-based courses, due to the hierarchical nature of technical knowledge [14]. Although PBL fosters creativity, collaboration, and real-world problem-solving, it can be undermined if students lack the core concepts necessary to navigate more advanced tasks. In the present study, the extended instructional sessions helped solidify foundational principles, thereby allowing students to approach projects with greater competence and confidence. As [13] suggest, while PBL thrives on hands-on engagement, structured teaching and well-placed assignments provide the essential scaffolding for meaningful application of theory.

Notably, the allocation of project implementation time was reduced from 15 to 6 weeks, yet the quality of student projects improved significantly. This counterintuitive outcome underscores how instructional design outweighs mere project duration [15, 16]. By dedicating additional time to guided instruction, students acquired a deeper conceptual understanding and encountered fewer obstacles during project work. This aligns with [17] view that inductive teaching strategies succeed when learners possess sufficient background knowledge to build upon. The enhanced confidence students reported also ties closely to self-efficacy theory, which posits that mastery experiences and adequate support increase one's belief in their capabilities [11, 12]. Thus, while the total project window was compressed, students' self-assurance and newly honed skills enabled them to work more efficiently, ultimately producing stronger outcomes.

4. Conclusion

This study investigated the impact of increasing teaching sessions from six to twelve in a first-year Computer Architecture course that employs a PBL framework. The results emphasize the importance of integrating fundamental instruction into PBL-oriented courses. The hierarchical nature of engineering knowledge necessitates that students develop a robust understanding of foundational topics before engaging in advanced, application-driven tasks. The intervention demonstrated that well-structured teaching sessions not only enhance technical proficiency but also reduce cognitive load, enabling students to work more efficiently during project implementation. This was particularly evident as project duration was reduced from 15 to 6 weeks without compromising the quality of project outcomes. Moreover, the study highlighted the role of guided tasks and active learning strategies in fostering student engagement and confidence. By moving beyond traditional lecture formats, the additional teaching sessions provided opportunities for hands-on exercises, collaborative problem-solving, and real-time feedback. These elements proved critical in equipping students with the skills and mindset needed for independent exploration and lifelong learning.

While the findings are promising, the study is not without limitations. The small sample size, lack of long-term observation, and potential influence of external factors such as student quality, workload, and prerequisite knowledge warrant caution in generalizing the results. Future research should address these limitations by employing larger sample sizes, longitudinal designs, and more comprehensive control of confounding variables to validate and extend these findings. However, this study contributes to the growing body of evidence supporting the integration of foundational instruction with project-based methodologies. It provides actionable insights for educators seeking to optimize course structures to enhance learning outcomes, particularly in technical disciplines. Educators can empower students to excel in both their academic and professional pursuits by prioritizing fundamentals, incorporating guided tasks, and creating supportive learning environments. These findings underline the critical role of instructional design in fostering student success, particularly in the early stages of engineering education.

REFERENCES

[1] Irit Sasson, Itamar Yehuda, and Noam Malkinson. Fostering the skills of critical thinking and question-posing in a project-based learning environment. *Thinking Skills and Creativity*, 29:203–212, September 2018. ISSN 1871-1871. doi: 10.1016/j.tsc.2018.08.001.

[2] Siti Khairani, Retno Dwi Suyanti, and Daulat Saragi. The influence of problem based learning (pbl) model collaborative and learning motivation based on students' critical thinking ability science subjects in class v state elementary school 105390 island image. *Budapest International Research and Critics in Linguistics and Education (BirLE) Journal*, 3(3):1581–1590, August 2020. ISSN 26552647. doi: 10.33258/birle.v3i3.1247.

[3] Enwei Xu, Wei Wang, and Qingxia Wang. The effectiveness of collaborative problem solving in promoting students' critical thinking: A meta-analysis based on empirical literature. *Humanities and Social Sciences Communications*, 10(1), January 2023. ISSN 2662-9992. doi: 10.1057/s41599023-01508-1.

[4] Rommel AlAli. Enhancing 21st century skills through integrated stem education using projectoriented problem-based learning. *GeoJournal of Tourism and Geosites*, 53(2):421–430, June 2024. ISSN 2065-0817. doi: 10.30892/gtg.53205-1217.

[5] J. C. Perrenet, P. A. J. Bouhuijs, and J. G. M. M. Smits. The suitability of problem-based learning for engineering education: Theory and practice. *Teaching in Higher Education*, 5(3):345–358, July 2000. ISSN 1470-1294. doi: 10.1080/713699144.

[6] Ashis Jalote Parmar. Bridging gaps in engineering education: Design thinking a critical factor for project based learning. In *2014 IEEE Frontiers in Education Conference (FIE) Proceedings*, volume 36, pages 1–8. IEEE, October 2014. doi: 10.1109/fie.2014.7044081.

[7] Llewellyn Mann, Rosemary Chang, Siva Chandrasekaran, Alicen Coddington, Scott Daniel, Emily Cook, Enda Crossin, Barbara Cosson, Jennifer Turner, Andrea Mazzurco, Jacqueline Dohaney, Tim O'Hanlon, Janine Pickering, Suzanne Walker, Francesca Maclean, and Timothy D. Smith. From problem-based learning to practice-based education: a framework for shaping future engineers. *European Journal of Engineering Education*, 46(1):27–47, January 2020. ISSN 1469-5898. doi: 10.1080/03043797.2019.1708867.

[8] Chris Perry and Andrea Allard. Making the connections: transition experiences for first-year education students. *The Journal of Educational Enquiry*, 4(2), 2003.

[9] Martin M. Chemers, Li-tze Hu, and Ben F. Garcia. Academic self-efficacy and first year college student performance and adjustment. *Journal of Educational Psychology*, 93(1):55–64, March 2001. ISSN 0022-0663. doi: 10.1037/0022-0663.93.1.55.

[10] Els C. M. van Rooij, Ellen P. W. A. Jansen, and Wim J. C. M. van de Grift. First-year university students' academic success: the importance of academic adjustment. *European Journal of Psychology of Education*, 33(4):749–767, November 2017. ISSN 1878-5174. doi: 10.1007/s10212-017-0347-8.

[11] Syed Ali Raza, Wasim Qazi, and Sara Qamar Yousufi. The influence of psychological, motivational, and behavioral factors on university students' achievements: the mediating effect of academic adjustment. *Journal of Applied Research in Higher Education*, 13(3):849–870, August 2020. ISSN 2050-7003. doi: 10.1108/jarhe-03-2020-0065.

[12] Luise von Keyserlingk, Julia Moeller, Jutta Heckhausen, Jacquelynne S. Eccles, and Richard Arum. Adjusting to college—do ability beliefs and confidence in getting support matter for performance and mental health? *Zeitschrift für Erziehungswissenschaft*, 27(1):123–146, September 2023. ISSN 1862-5215. doi: 10.1007/s11618-023-01185-5.

[13] Richard M. Felder and Rebecca Brent. Teaching and learning stem: A practical guide. *John Wiley & Sons*, 2024.

[14] Christoph Deeken, Irene Neumann, and Aiso Heinze. Mathematical prerequisites for stem programs: What do university instructors expect from new stem undergraduates? *International Journal of Research in Undergraduate Mathematics Education*, 6(1):23–41, August 2019. ISSN 2198-9753. doi: 10.1007/s40753-019-00098-1.

[15] Alisa Morss Clyne and Kristen L. Billiar. Problem-based learning in biomechanics: Advantages, challenges, and implementation strategies. *Journal of Biomechanical Engineering*, 138(7), June 2016. ISSN 1528-8951. doi: 10.1115/1.4033671.

[16] Sutrisno Sadji Evenddy, Nurhaeda Gailea, and Syafrizal Syafrizal. Exploring the benefits and challenges of project-based learning in higher education. *PPSDP International Journal of Education*, 2 (2):458–469, November 2023. ISSN 2830-3229. doi: 10.59175/pijed.v2i2.148.

[17] Michael J. Prince and Richard M. Felder. Inductive teaching and learning methods: Definitions, comparisons, and research bases. *Journal of Engineering Education*, 95(2):123–138, April 2006. ISSN 1069-4730. doi: 10.1002/j.2168-9830.2006.tb00884.x.