Implementation of Project-Based Learning in CAD Education to Support Machine Design Drawing Skills

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Abstract

This study aims to describe the implementation of Project-Based Learning (PjBL) in 3D CAD learning using Autodesk Fusion 360, to measure the improvement in students' abilities to develop creativity, collaboration, and communication, and to evaluate the competency in 3D CAD drawing of machine designs with Autodesk Fusion 360. This research employs classroom action research, carried out through planning, execution, observation, and reflection across at least three cycles. The study involved 43 students taking the 3D CAD course in the Department of Mechanical Engineering Education, Faculty of Engineering, Yogyakarta State University. The results showed that PjBL implementation in CAD learning includes project preparation, execution, and presentation of project results. Students' abilities in creativity, collaboration, and communication significantly improved, with average scores of 83.7, 84.4, and 80.4, respectively. Additionally, the average competency in 3D CAD machine design drawing achieved was 88.66. This indicates that students were able to effectively apply their skills in practical, real-world projects, demonstrating a high level of proficiency in using Autodesk Fusion 360 for machine design. The study concludes that PjBL is an effective method for enhancing both the technical and soft skills of students in CAD learning environments.

Keywords: Project-Based Learning, 3D CAD, Machine Design, Autodesk Fusion 360, Creativity, Collaboration, Communication.

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the Indonesian Ministry of Education, Culture, Research, and Technology is a testament to this evolution. This initiative aims to provide educators with the freedom to develop curricula that are responsive to local needs and conditions, thereby enhancing the quality of higher education in Indonesia. One of the pedagogical approaches that align well with the principles of MBKM is Project-Based Learning (PjBL) [1].

Project-Based Learning (PjBL) is a student-centered pedagogy that involves a dynamic classroom approach in which students acquire a deeper knowledge through active exploration of real-world challenges and problems. This approach is particularly effective in fostering practical skills and preparing students for the professional world. Within the context of engineering education, PjBL has shown promise in bridging the gap between theoretical knowledge and practical application [2].The Department of Mechanical Engineering Education at Yogyakarta State University is among the institutions that have embraced this innovative approach. The department offers various courses, including Computer-Aided Design (CAD), which is integral to modern engineering education. CAD is crucial in the era of digitalization and the Fourth Industrial Revolution, serving as a fundamental tool for creating precise and complex design models [3].

Despite its importance, traditional CAD education often falls short in engaging students actively. Conventional methods typically involve passive learning, where students listen to lectures and complete individual tasks. This approach limits opportunities for developing essential skills such as creativity, collaboration, and communication. The integration of PjBL into CAD courses can address these shortcomings by providing a more engaging and interactive learning experience [4]. The traditional approach to teaching CAD, primarily through lectures and individual assignments, has several inherent limitations. First, it does not sufficiently stimulate students' creative thinking. Creativity is a critical skill in engineering, enabling students to develop innovative solutions to complex problems. However, the passive nature of traditional lectures does not encourage the exploration of new ideas or the application of creative problem-solving techniques [5]. Second, traditional CAD education often lacks opportunities for collaboration. In the professional world, engineers frequently work in teams, requiring strong collaboration skills. The ability to communicate effectively, share ideas, and work towards common goals is essential. However, individual assignments do not provide the necessary environment for students to develop these skills [6]. Third, communication skills are not adequately addressed in conventional CAD courses. Effective communication is crucial in engineering, whether it involves presenting ideas to stakeholders, documenting designs, or collaborating with team members. Traditional methods, which focus on individual work and technical skills, often neglect the development of communication skills [7].

Furthermore, the advent of Industry 4.0 and the increasing integration of digital technologies in manufacturing necessitate a shift in educational practices. The ability to use CAD software proficiently is not enough; students must also be adept at working in digital environments that require constant collaboration and communication. This new landscape demands that educational institutions adopt teaching methodologies that prepare students for these challenges [8].

The limitations of traditional CAD education are also evident in students' performance and engagement. Studies have shown that passive learning methods can lead to disengagement and lower retention rates [9]. In contrast, active learning approaches like PjBL have been found to enhance student engagement, motivation, and retention. For instance, a study by Prince [10] indicated that active learning strategies significantly improve students' understanding and retention of course material compared to traditional lectures. The theoretical underpinning of Project-Based Learning (PjBL) can be traced back to the constructivist theories of education, particularly the works of Jean Piaget and Lev Vygotsky. Constructivism posits that learners construct knowledge through experiences and interactions with their environment. PjBL embodies this principle by engaging students in meaningful projects that require active exploration and problem-solving [11], [12].

Jean Piaget's theory of cognitive development emphasizes the role of active engagement in learning. According to Piaget, learners move through different stages of cognitive development, each characterized by distinct ways of thinking and understanding the world. PjBL aligns with this theory by providing students with opportunities to engage in hands-on projects that challenge their cognitive abilities and promote deeper understanding [11]. Lev Vygotsky's social constructivist theory further supports the use of PjBL. Vygotsky emphasized the importance of social interaction and collaboration in learning. His concept of the Zone of Proximal Development (ZPD) highlights the potential for learning that occurs when students work collaboratively with peers or under the guidance of a more knowledgeable individual. PjBL leverages this concept by encouraging teamwork and peer learning [12].

Recent research supports the efficacy of PjBL in enhancing student learning outcomes. A study by Helle, Tynjälä, and Olkinuora [13] found that PjBL enhances students' problem-solving skills and promotes a deeper understanding of subject matter. Similarly, a meta-analysis by Chen and Yang [14] concluded that PjBL positively impacts students' academic performance, critical thinking, and motivation. More recent studies have further validated these findings. For instance, García-González et al. [15] demonstrated that PjBL improves students' engagement and academic performance in engineering courses. Additionally, a study by Walker and Leary [16] highlighted the benefits of PjBL in fostering collaborative skills and enhancing learning experiences in higher education.

Another study by ChanLin [17] found that PjBL not only enhances technical skills but also improves students' attitudes towards learning and their ability to work collaboratively. This is particularly relevant in engineering education, where both technical and soft skills are crucial for professional success. The integration of PjBL into CAD courses can thus provide a more holistic education that prepares students for the multifaceted challenges of the engineering profession.

Furthermore, the use of digital tools in PjBL, such as Autodesk Fusion 360, has been shown to enhance the learning experience by providing students with hands-on experience in a simulated professional environment. According to Al-Ani [18], the integration of digital tools in PjBL fosters a deeper understanding of course content and equips students with practical skills that are directly applicable in the workforce.

Despite the documented benefits of PjBL, its implementation in CAD education remains limited. This gap is evident in the lack of comprehensive studies examining the impact of PjBL on CAD learning outcomes. Most existing research focuses on general STEM education or specific engineering disciplines, with few studies addressing the unique challenges and opportunities associated with integrating PjBL into CAD courses [19].

Moreover, there is a need for research that explores the practical aspects of implementing PjBL in CAD education. This includes understanding how to effectively design and manage projects, assess student performance, and address potential challenges such as resource constraints and varying levels of student preparedness. By addressing these gaps, the current study aims to contribute to the body of knowledge on PjBL and provide practical insights for educators seeking to enhance CAD education [20].

The gap also extends to the assessment methods used in PjBL. Traditional assessment methods may not adequately capture the skills and competencies developed through PjBL, such as creativity, collaboration, and communication. Innovative assessment strategies that align with the principles of PjBL are needed to provide a more accurate measure of student learning and development.

Additionally, there is a paucity of research on the long-term impacts of PjBL on students' career success and professional development. While existing studies highlight the immediate benefits of PjBL in terms of academic performance and skill development, more longitudinal studies are needed to examine how these benefits translate into professional success and career advancement [21].

This study is significant for several reasons. First, it contributes to the growing body of literature on PjBL by exploring its application in CAD education. By doing so, it addresses a gap in existing research and provides valuable insights into how PjBL can enhance learning outcomes in this specific context.

Second, the study offers practical guidance for educators. By documenting the process of implementing PjBL in a CAD course, it provides a roadmap that other educators can follow. This includes detailed descriptions of project design, execution, and assessment, as well as strategies for overcoming common challenges [22].

Third, the study highlights the benefits of PjBL in fostering essential skills such as creativity, collaboration, and communication. These skills are crucial for success in the modern engineering profession and are often neglected in traditional CAD education. By demonstrating how PjBL can address this gap, the study provides a compelling case for its broader adoption in engineering education [23].

Furthermore, this study introduces an innovative approach by integrating Autodesk Fusion 360 into the PjBL framework. Autodesk Fusion 360 is a cloud-based CAD tool that facilitates collaboration and provides a comprehensive platform for design and engineering. The use of such advanced tools in PjBL can significantly enhance the learning experience by providing students with access to cutting-edge technology and enabling them to work on realistic and complex projects [24].

The study also examines the role of digital literacy in modern engineering education. As digital tools become increasingly prevalent in the industry, there is a growing need for students to develop strong digital literacy skills. This study explores how PjBL, combined with the use of digital tools like Autodesk Fusion 360, can enhance students' digital literacy and prepare them for the demands of the modern workforce [25].

Based on the background, problem analysis, and theoretical foundation outlined above, the objectives of this study are as follows:

1. To describe the implementation of Project-Based Learning (PjBL) in 3D CAD learning using Autodesk Fusion 360. This objective focuses on providing a detailed account of how PjBL can be integrated into CAD education. This includes the design and execution of projects, the use of Autodesk Fusion 360, and the strategies employed to engage students and facilitate learning.
2. To measure the improvement in students' abilities to develop creativity, collaboration, and communication. This objective aims to evaluate the impact of PjBL on students' soft skills. These skills are essential for success in the engineering profession and are often overlooked in traditional CAD education. By measuring improvements in these areas, the study seeks to demonstrate the value of PjBL in fostering well-rounded engineers.
3. To evaluate the competency in 3D CAD drawing of machine designs with Autodesk Fusion 360. This objective focuses on assessing students' technical skills in 3D CAD drawing. Competency in CAD is a critical outcome of engineering education, and the study aims to determine how effectively PjBL can enhance this competency. This includes evaluating students' ability to use Autodesk Fusion 360 to create precise and complex design models.

In conclusion, this study seeks to address the limitations of traditional CAD education by integrating Project-Based Learning (PjBL) into the curriculum. By doing so, it aims to enhance students' creativity, collaboration, and communication skills, as well as their technical competency in 3D CAD drawing. The study is grounded in constructivist theories of education and supported by recent research on the benefits of PjBL. By addressing existing gaps in the literature and providing practical insights for educators, the study aims to contribute to the ongoing efforts to improve engineering education in Indonesia.

2. METHODS

The methodology section outlines the systematic approach used in this study to investigate the implementation of Project-Based Learning (PjBL) in 3D CAD learning using Autodesk Fusion 360. This section covers the research design, participants, data collection methods, data analysis techniques, and ethical considerations. The goal is to provide a clear and detailed description that enables replication and ensures the study’s reliability and validity.

This study employs a Classroom Action Research (CAR) design, a methodology widely used in educational research to improve teaching practices and student learning outcomes. CAR involves a cyclic process of planning, acting, observing, and reflecting, allowing researchers to make iterative improvements based on feedback and observations. This approach is particularly suitable for investigating the implementation of PjBL in a classroom setting, as it provides a structured framework for continuous improvement and adaptation [26].

The CAR design was selected for its flexibility and responsiveness to the dynamic nature of classroom environments. By engaging in iterative cycles, the researcher can identify and address challenges as they arise, making adjustments to enhance the effectiveness of PjBL in 3D CAD learning. This design also facilitates collaboration between the researcher and participants, fostering a participatory approach that aligns with the principles of PjB.

The participants in this study were 43 students enrolled in the 3D CAD course at the Department of Mechanical Engineering Education, Faculty of Engineering, Yogyakarta State University. The students were in their third year of study and had prior experience with basic CAD concepts and software. The course is a mandatory component of the curriculum, ensuring a diverse group of students with varying levels of proficiency and interest in CAD [27].

The selection of participants was based on purposive sampling, a non-probability sampling technique commonly used in educational research. This method involves selecting individuals who are most likely to provide relevant and insightful data based on specific characteristics or criteria [28]. In this case, the criteria included enrollment in the 3D CAD course and willingness to participate in the study. The diversity of the participant group was advantageous for examining the implementation of PjBL, as it allowed for the observation of different responses and adaptations to the learning approach. The inclusion of students with varying levels of CAD proficiency provided a comprehensive view of the challenges and benefits associated with PjBL in 3D CAD learning.

Data collection for this study was conducted using multiple methods to ensure a comprehensive understanding of the implementation of PjBL. The primary data collection methods included observations, surveys, interviews, and document analysis. These methods were chosen to capture both quantitative and qualitative data, providing a rich and detailed picture of the learning process and outcomes.

Observations were conducted throughout the course to monitor the implementation of PjBL and student engagement. The researcher used a structured observation guide to record specific behaviors and interactions related to creativity, collaboration, and communication. The guide included predefined categories and indicators to ensure consistency and reliability in the data collection process [29].

Observations were conducted during class sessions, group work, and project presentations. The researcher took detailed field notes and used video recordings to capture interactions and activities. This approach allowed for a thorough analysis of the learning environment and provided insights into how students engaged with the PjBL approach and the CAD software.

Surveys were administered to gather quantitative data on students' perceptions and experiences with PjBL. The survey instrument included Likert-scale questions to measure students' self-reported levels of creativity, collaboration, and communication skills before and after the implementation of PjBL. Additionally, open-ended questions were included to capture qualitative data on students' experiences and suggestions for improvement.

The surveys were administered at three key points: before the start of the course (pre-survey), at the midpoint of the course (mid-survey), and at the end of the course (post-survey). This longitudinal approach allowed the researcher to track changes in students' perceptions and skills over time, providing valuable data on the impact of PjBL.

Semi-structured interviews were conducted with a subset of participants to gain deeper insights into their experiences with PjBL. The interview guide included open-ended questions designed to explore students' perspectives on the learning process, the challenges they faced, and the benefits they perceived. Interviews were also conducted with the course instructor to gather data on the instructional strategies used and the overall effectiveness of PjBL.

The semi-structured format allowed for flexibility in the interviews, enabling the researcher to probe further into interesting or unexpected responses. Interviews were audio-recorded with the participants' consent and transcribed verbatim for analysis. This qualitative data provided rich, detailed accounts of students' experiences and supplemented the quantitative data collected through surveys.

Document analysis involved the review of various documents related to the course and the projects completed by students. These documents included course syllabi, project guidelines, student work (e.g., CAD models, project reports), and assessment rubrics. Document analysis provided additional data on the structure and content of the course, the nature of the projects, and the criteria used to assess student performance.

The analysis of student work was particularly valuable for evaluating the technical competency of students in 3D CAD drawing. By examining the CAD models and project reports, the researcher could assess the quality and complexity of the designs, as well as the application of CAD techniques and tools. This data complemented the observational and survey data, providing a comprehensive view of students' learning outcomes.

Data analysis involved both quantitative and qualitative methods to ensure a thorough examination of the collected data. The analysis was conducted in several stages, including data preparation, coding, and interpretation.

Quantitative data from surveys were analyzed using descriptive and inferential statistics. Descriptive statistics, such as means, standard deviations, and frequency distributions, were used to summarize the data and provide an overview of students' self-reported skills and perceptions. Inferential statistics, including paired t-tests and ANOVA, were used to examine changes in students' skills over time and to determine the statistical significance of the findings [30].

The use of inferential statistics allowed the researcher to make generalizations about the impact of PjBL on the larger population of students. By comparing pre-survey and post-survey data, the researcher could assess the effectiveness of PjBL in enhancing creativity, collaboration, and communication skills.

Qualitative data from interviews, observations, and open-ended survey responses were analyzed using thematic analysis. Thematic analysis involves identifying, analyzing, and reporting patterns (themes) within the data. The process includes several steps: familiarization with the data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the report [31].

The researcher began by reading and re-reading the interview transcripts, observation notes, and open-ended survey responses to become familiar with the data. Initial codes were then generated to capture significant features of the data related to the research questions. These codes were grouped into themes that represented broader patterns in the data.

The themes were reviewed and refined to ensure they accurately reflected the data and provided a coherent understanding of the participants' experiences. The final themes were defined and named, and illustrative quotes from the data were selected to support the findings. This qualitative analysis provided rich, detailed insights into the implementation of PjBL and the students' experiences.

The integration of quantitative and qualitative data, known as mixed-methods analysis, was used to provide a comprehensive understanding of the research findings. This approach involved triangulating data from different sources to validate and enrich the findings. For example, survey data on students' self-reported skills were compared with observational data on classroom interactions and qualitative data from interviews.

Mixed-methods analysis allowed the researcher to explore the relationships between different types of data and to identify areas where the findings converged or diverged. This approach enhanced the robustness of the study by providing multiple perspectives on the research questions [31].

3. RESULTS AND DISCUSSION

This section presents the findings of the study on the implementation of Project-Based Learning (PjBL) in 3D CAD learning using Autodesk Fusion 360. The results are organized into several key areas: improvements in creativity, collaboration, and communication skills; technical competency in 3D CAD drawing; and overall student engagement and satisfaction. Each subsection includes detailed analyses of quantitative and qualitative data, followed by a discussion that relates the findings to existing literature and theoretical frameworks.

3.1 Creativity

The implementation of PjBL aimed to enhance students' creative thinking abilities. Creativity was measured through pre-surveys and post-surveys, observational data, and analysis of students' project work.

Quantitative Findings

Quantitative data from the surveys indicated a significant improvement in students' self-reported creativity scores. The pre-survey results showed an average creativity score of 65.4, which increased to 83.7 in the post-survey (see Table 1 for detailed statistics). This increase was statistically significant, as confirmed by a paired t-test ($t = 7.85$, $p < 0.001$).

Table 1. Creativity Scores (Pre and Post-Survey)

Survey	Mean	Standard Deviation	t-value	p-value
Pre	65.4	8.7		
Post	83.7	6.4	7.85	<0.001

Qualitative Findings

Qualitative data from observations and interviews supported the quantitative findings. Observations revealed that students engaged in more divergent thinking and were more willing to explore unconventional solutions during project work. Interviews with students highlighted their increased confidence in their creative abilities and their appreciation for the freedom to experiment with different design approaches.

Discussion

The improvement in creativity aligns with the theoretical foundations of PjBL, which emphasize active learning and exploration [11], [12]. The findings also corroborate existing research that links PjBL with enhanced creative thinking [14]. The structured yet flexible nature of PjBL projects allowed students to approach problems creatively, fostering an environment where innovation could flourish.

3.2 Collaboration

Collaboration is a critical skill in engineering education and professional practice. This study assessed improvements in collaboration through surveys, observations, and group project evaluations.

Quantitative Findings

The survey data indicated a substantial increase in students' collaboration skills. The mean collaboration score rose from 67.8 in the pre-survey to 84.4 in the post-survey, with a statistically significant t-value of 8.12 ($p < 0.001$) (see Table 2).

Table 2. Collaboration Scores (Pre and Post-Survey)

Qualitative Findings

Observations and interviews provided deeper insights into the collaborative dynamics. Students were observed to engage in more effective communication, share responsibilities equitably, and resolve conflicts constructively. Interviews revealed that students valued the teamwork aspect of PjBL and felt that it prepared them for real-world engineering scenarios.

Discussion

The enhancement in collaboration skills is consistent with Vygotsky's social constructivist theory, which underscores the importance of social interaction in learning [12] The collaborative nature of PjBL projects required students to work closely together, facilitating the development of teamwork and communication skills. These findings are supported by previous studies that highlight the benefits of PjBL for collaboration [19].

3.3 Communication

Effective communication is essential for successful project execution and professional development. This study evaluated changes in students' communication skills through surveys, observations, and project presentations.

Quantitative Findings

Survey results demonstrated a notable improvement in communication skills, with the mean score increasing from 62.3 in the pre-survey to 80.4 in the post-survey. This improvement was statistically significant, as indicated by a paired t-test ($t = 7.33$, $p < 0.001$) (see Table 3).

Table 3. Communication Scores (Pre and Post-Survey)

Survey	Mean	Standard Deviation	t-value	p-value
Pre	62.3	9.2		

Post	80.4	6.5	7.33	<0.001

Qualitative Findings

Observational data showed that students became more proficient in articulating their ideas, both in written and verbal forms. During project presentations, students exhibited improved presentation skills, including clearer explanations of their design choices and more confident delivery. Interviews highlighted students' recognition of the importance of communication and their appreciation for the opportunities to practice these skills in a supportive environment.

Discussion

The observed improvement in communication skills aligns with the goals of PjBL, which emphasizes the development of both technical and soft skills. The findings are consistent with research indicating that PjBL enhances communication abilities by providing authentic contexts for practicing these skills [6], [7]. The structured opportunities for presenting and discussing projects contributed to students' confidence and proficiency in communication.

3.4 Technical Competency in 3D CAD Drawing

The primary objective of this study was to evaluate the impact of PjBL on students' technical competency in 3D CAD drawing using Autodesk Fusion 360. Competency was assessed through the quality and complexity of students' CAD models, project reports, and performance on practical exams.

Quantitative Findings

The analysis of CAD models and project reports revealed significant improvements in students' technical skills. The average score for technical competency increased from 70.2 at the beginning of the course to 88.7 by the end, with a statistically significant t-value of 9.45 ($p < 0.001$) (see Table 4).

Table 4.Technical Competency Scores (Pre and Post-Assessment)

Assessment	Mean	Standard Deviation	t-value	p-value
Pre	70.2	8.3		
Post	88.7	6.1	9.45	<0.001

Qualitative Findings

Qualitative analysis of students' CAD models showed increased complexity and precision in their designs. Students demonstrated a better understanding of CAD tools and techniques, as well as the ability to apply them effectively in their projects. Interviews with students revealed that they felt more confident in their CAD skills and appreciated the hands-on experience provided by PjBL.

Discussion

The substantial improvement in technical competency aligns with the constructivist principles underlying PjBL, which emphasize learning through doing and the application of knowledge in practical contexts [11]. The findings are consistent with previous studies that have demonstrated the effectiveness of PjBL in enhancing technical skills in STEM education[2], [14]. The use of Autodesk Fusion 360 provided a professional-grade platform for students to practice and refine their CAD skills, contributing to their overall competency.

3.5 Overall Student Engagement and Satisfaction

Student engagement and satisfaction were critical indicators of the success of the PjBL implementation. These aspects were assessed through surveys, observations, and interviews.

Quantitative Findings

Survey results indicated high levels of student engagement and satisfaction with the PjBL approach. The mean engagement score was 85.6, and the mean satisfaction score was 87.3 (see Table 5 for detailed statistics). Both scores were significantly higher than those typically reported for traditional lecture-based courses.

Table 5. Engagement and Satisfaction Scores

Measure	Mean	Standard Deviation
Engagement	85.6	7.4
Satisfaction	87.3	6.9

Qualitative Findings

Observations showed that students were more actively involved in their learning, participating enthusiastically in group discussions and project activities. Interviews revealed that students appreciated the hands-on nature of PjBL and felt that it made the learning experience more relevant and enjoyable. Many students mentioned that the projects helped them see the practical applications of CAD skills, increasing their motivation to learn.

Discussion

The high levels of engagement and satisfaction observed in this study are consistent with the literature on PjBL, which suggests that active learning approaches enhance student motivation and interest [4],[6]. The opportunity to work on real-world projects and collaborate with peers contributed to a more engaging and meaningful learning experience. These findings highlight the potential of PjBL to transform traditional educational practices and improve student outcomes.

3.6 Comparison with Existing Literature

The findings of this study are in line with existing research on the benefits of PjBL in STEM education. Studies have consistently shown that PjBL enhances critical thinking, problem-solving, and technical skills [19], [14] The improvements in creativity, collaboration, and communication observed in this study are supported by the theoretical frameworks of Piaget [11] and Vygotsky [12], which emphasize active and social learning.

The significant increase in technical competency is particularly noteworthy, as it addresses a critical gap in traditional CAD education. Previous studies have highlighted the limitations of passive learning approaches in developing practical skills [9].By integrating PjBL with advanced digital tools like Autodesk Fusion 360, this study demonstrates an effective strategy for enhancing both technical and soft skills in engineering education.

3.7 Practical Implications

The findings of this study have several practical implications for educators and curriculum developers. First, the successful implementation of PjBL in 3D CAD learning provides a model for other institutions seeking to enhance their engineering education programs. The detailed description of the project design, execution, and assessment can serve as a guide for educators interested in adopting similar approaches.

Second, the study highlights the importance of providing students with opportunities to practice and develop soft skills, such as creativity, collaboration, and communication. These skills are essential for success in the modern engineering profession and should be integrated into the curriculum alongside technical training.

Third, the use of advanced digital tools like Autodesk Fusion 360 in PjBL projects can significantly enhance the learning experience and better prepare students for the demands of the workforce. Educators should consider incorporating such tools into their teaching practices to provide students with hands-on experience and improve their technical competency.

3.8 Limitations of the Study

Despite the positive findings, this study has several limitations that should be acknowledged. First, the study was conducted with a specific group of students in a single institution, which may limit the generalizability of the findings. Future research should consider replicating the study with diverse student populations and in different educational contexts to enhance the generalizability of the results.

Second, the study relied on self-reported data from surveys and interviews, which may be subject to social desirability bias. While efforts were made to ensure anonymity and confidentiality, participants may have provided responses they perceived as desirable or expected. The use of multiple data sources, including observations and document analysis, helped mitigate this limitation.

Third, the implementation of PjBL and the use of Autodesk Fusion 360 were new experiences for both the students and the instructor. The novelty of the approach may have influenced the results, as participants were adapting to new methods and tools. Future research could examine the long-term impacts of PjBL and the continued use of digital tools in CAD education.

3.9 Future Research Directions

Future research should build on the findings of this study to further explore the potential of PjBL in engineering education. Several avenues for future research are suggested:

1. Longitudinal Studies: Conducting longitudinal studies to examine the long-term impacts of PjBL on students' career success and professional development. Such studies could provide valuable insights into how the skills and competencies developed through PjBL translate into professional practice.
2. Comparative Studies: Comparing the effectiveness of PjBL with other active learning approaches, such as problem-based learning or flipped classrooms, to identify the most effective strategies for enhancing technical and soft skills in engineering education.
3. Diverse Contexts: Replicating the study with diverse student populations and in different educational contexts to enhance the generalizability of the findings. This could include studies in different countries, institutions, and disciplines.
4. Assessment Methods: Developing and testing innovative assessment methods that align with the principles of PjBL. These methods should capture the full

range of skills and competencies developed through PjBL, including creativity, collaboration, and communication.

5. Technology Integration: Exploring the use of other advanced digital tools and technologies in PjBL projects. This could include virtual reality, augmented reality, and artificial intelligence, which have the potential to further enhance the learning experience and technical competency of students.

4. CONCLUSION

The implementation of Project-Based Learning (PjBL) in 3D CAD learning using Autodesk Fusion 360 has proven to be highly effective in enhancing students' creativity, collaboration, communication skills, and technical competency. The findings of this study provide strong evidence for the benefits of PjBL and offer practical guidance for educators seeking to improve their teaching practices. By addressing the limitations and exploring future research directions, educators and researchers can continue to advance the field of engineering education and better prepare students for the challenges of the modern workforce.

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