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Project based Learning Integrated with CAD Software to Improve Technical Drawing Skills

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Abstract
This study investigates the impact of Project Based Learning (PBL) integrated with Computer Aided Design (CAD) software on improving technical drawing skills among vocational high school students. The experimental design involved two groups: an experimental group that received PBL based instruction using CAD software, and a control group that followed traditional instructional methods. The results revealed a significant improvement in the technical drawing skills of the experimental group, as indicated by higher post-test scores compared to the control group. These findings suggest that PBL, when coupled with CAD tools, fosters active learning, critical thinking, and enhances students' ability to visualize and create accurate technical drawings. Additionally, the project-based approach promoted collaboration, real world problem solving, and digital literacy, key competencies in vocational education. The study also identified a substantial effect size (Cohens d=2.97), emphasizing the significant educational impact of the PBL CAD integration. Despite the promising results, the study highlights limitations in terms of generalizability due to the single school sample and suggests further exploration of affective and behavioral outcomes in future research. In conclusion, the integration of PBL and CAD software represents an effective pedagogical strategy for improving technical drawing skills and preparing students for the demands of the modern workforce.

Keywords
cad software; experimental study; project based learning; technical drawing skills

INTRODUCTION

Technical drawing is a fundamental competency for students in vocational education, particularly those specializing in building design and construction. It serves as the foundation for interpreting and communicating architectural and structural plans,

which are essential skills required in the construction industry (Zhou & Wang, 2025). However, conventional teaching methods that rely heavily on manual drawing exercises and teacher centered instruction often fail to sufficiently engage students or reflect the practical demands of modern workplaces (Bhardwaj et al., 2025).

In recent years, the integration of digital tools, such as Computer Aided Design (CAD) software, has become increasingly essential in architectural and engineering practices. CAD not only enhances the precision and clarity of technical drawings but also fosters students' spatial awareness and creativity (Totuk et al., 2025). Despite its relevance, the effective incorporation of CAD in vocational high school curricula remains limited, particularly in developing regions where instructional approaches often lag technological advancements (Ndjama, 2025).

Project Based Learning (PBL) offers a promising pedagogical framework to address this gap. By engaging students in real-world tasks and collaborative problem-solving, PBL encourages active learning, critical thinking, and the application of knowledge in authentic contexts (Trisnawati et al., 2025). When integrated with CAD software, PBL has the potential to create a dynamic learning environment that mirrors industry practices while simultaneously developing students' technical drawing competencies (Alvarez et al., 2025).

This study aims to examine the effectiveness of Project Based Learning integrated with CAD software in improving the technical drawing skills of vocational high school students. Conducted at SMK Negeri 2 Kupang in Indonesia, the study compares students performance between those who received PBL CAD instruction and those who followed conventional learning methods. The findings of this research are expected to contribute to the ongoing development of digital based instructional strategies in vocational education and provide empirical support for curriculum innovation aligned with industry needs.

LITERATURE REVIEW

Technical drawing is an essential skill in vocational education, particularly within the fields of architecture, civil engineering, and construction. It enables students to interpret, design, and communicate building plans with precision and accuracy. According to Chang et al. (2024), technical drawing serves not only as a communicative medium but also as a cognitive tool that enhances students' understanding of spatial relationships and

construction logic. However, the traditional approach to teaching technical drawing often emphasizes rote learning and manual drafting, which may not adequately prepare students for the demands of modern industry (Evangelista, 2025).

The use of Computer-Aided Design (CAD) software has transformed the way technical drawings are created and understood in professional settings. CAD allows users to produce detailed, scalable, and modifiable drawings, which are critical for real-time problem-solving in design and construction processes (Barjuei et al., 2024). Studies have shown that integrating CAD into the curriculum significantly enhances students' technical competence, accuracy, and efficiency in drawing tasks (Nuryanto et al., 2025). However, the adoption of CAD in vocational education is often limited by factors such as lack of infrastructure, inadequate teacher training, and curriculum rigidity (Al-Worafi & Ali, 2024).

Project Based Learning (PBL) is a student centered instructional strategy that organizes learning around authentic tasks and real world challenges. It has been widely recognized for fostering critical thinking, collaboration, and applied knowledge in vocational education (Fricticarani et al., 2025; Hakiki et al., 2024). In the context of technical education, PBL provides opportunities for learners to engage in meaningful design projects that simulate industry scenarios. According to Yu (2024), PBL enhances problem solving skills and contextual understanding by encouraging learners to take ownership of their learning process.

The integration of PBL with CAD based instruction represents a pedagogical innovation that combines hands-on project work with digital competencies. Several studies have reported that such integration improves student engagement, motivation, and learning outcomes (Zaher et al., 2023). By allowing students to design real life structures using professional tools, PBL CAD approaches bridge the gap between theory and practice, aligning education with workplace expectations. Nonetheless, empirical evidence on the effectiveness of this approach in vocational high schools remains limited, especially in the Southeast Asian context.

This literature review highlights the need for further empirical investigation into the impact of combining PBL with CAD tools in improving technical drawing skills. The present study seeks to fill this gap by conducting an experimental study at a vocational

high school in Indonesia, thereby contributing to both pedagogical theory and vocational education practice.

METHOD

This study employed a quasi experimental research design with a non equivalent control group pre-test post-test approach (Yassin & Bashir, 2024). Figure 1, presents the quasi experimental research procedure.

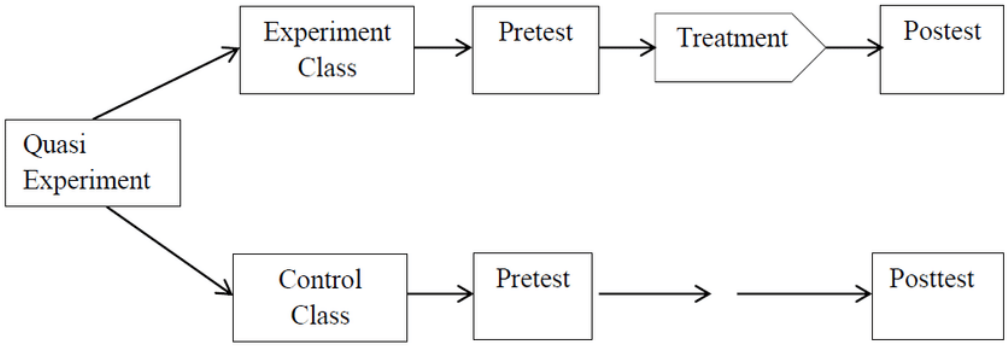

Figure 1. quasi-experimental research design

The design was selected to compare the effectiveness of Project Based Learning (PBL) integrated with CAD software against conventional instructional methods in enhancing students technical drawing skills. Both the experimental and control groups received pre-tests and post-tests to assess learning outcomes, but only the experimental group was exposed to the PBL CAD intervention. This design allowed the researchers to observe causal relationships while maintaining ecological validity in an authentic school setting.

Participants And Sampling

The participants were students from the Department of Building Modeling and Information Design at SMK Negeri 2 Kupang, a vocational high school in East Nusa Tenggara, Indonesia. A total of 60 students were selected using purposive sampling, based on class availability and teacher recommendations. The students were then divided into two groups: the experimental group (n = 30) received instruction through the PBL CAD model, while the control group (n = 30) was taught using traditional teacher centered

methods. Both groups had equivalent academic backgrounds based on prior semester grades and demographic characteristics.

Research Instruments

Data collection was conducted using a technical drawing skill assessment, developed and validated by experts in vocational education and instructional design. The instrument consisted of performance-based tasks aligned with the vocational curriculum and industry standards. The assessment was administered as both a pre-test and a post-test to measure students' ability to produce accurate, clear, and detailed architectural drawings. Instrument validity was ensured through expert review, and the reliability coefficient (Cronbach's alpha) was calculated at 0.89, indicating high internal consistency.

Data Analysis Techniques

Quantitative data from pre-tests and post-tests were analyzed using descriptive statistics (mean and standard deviation) and inferential statistics, including paired sample t-tests to determine within-group differences and independent sample t-tests to evaluate between-group differences. The significance level was set at $p < 0.05$. All statistical analyses were conducted using SPSS version 26. In addition, effect size (Cohen's d) was calculated to determine the magnitude of the intervention's impact.

RESULT AND DISCUSSION

RESULT

This section presents the quantitative findings of the study, focusing on the comparison of students' technical drawing skills before and after the implementation of Project-Based Learning integrated with CAD software.

Pre-Test and Post-Test Descriptive Statistics

To evaluate the effectiveness of the PBL CAD model, both experimental and control groups were assessed using a standardized technical drawing test administered before and after the intervention. The descriptive statistics of both groups are presented in Table 1.

Table 1. Descriptive Statistics of Technical Drawing Test Scores

Group	Test Type	N	Mean	Std. Deviation
Experimental	Pre-test	30	68.47	6.31
Experimental	Post-test	30	85.93	5.25
Control	Pre-test	30	67.80	6.54
Control	Post-test	30	74.23	6.08

The mean post-test score of the experimental group (M = 85.93, SD = 5.25) was significantly higher than the control group (M = 74.23, SD = 6.08), suggesting a substantial improvement attributable to the intervention.

Within Group Comparison (Paired Sample t-Test)

A paired sample t-test was conducted to assess the improvement within each group. The results are summarized in Table 2.

Table 2. Paired Sample t-Test Results (Pre-Test vs Post-Test)

Group	t	df	p-value	Cohen's d
Experimental	-16.27	29	< 0.001	2.97
Control	-7.58	29	< 0.001	1.38

Both groups showed statistically significant improvement ($p < 0.001$). However, the effect size for the experimental group (Cohen's $d = 2.97$) was more than double that of the control group (Cohen's $d = 1.38$), indicating a very large effect from the PBL-CAD intervention.

Between Group Comparison (Independent Sample t-Test)

An independent sample t-test was conducted to compare the post-test scores between the two groups.

Table 3. Independent Sample t-Test of Post-Test Scores

Groups Compared	t	df	p-value	Mean Difference
Experimental vs Control	7.96	58	< 0.001	11.70

The results showed a statistically significant difference between the experimental and control groups' post-test scores ($p < 0.001$), with the experimental group achieving higher technical drawing competence.

The data clearly indicate that students taught using Project-Based Learning integrated with CAD software demonstrated significantly higher improvement in technical

drawing skills compared to those receiving conventional instruction. The intervention produced a large effect size and meaningful learning gains.

DISCUSSION

The results of this study indicate that the integration of Project Based Learning (PBL) with Computer Aided Design (CAD) software significantly enhances technical drawing skills among vocational high school students. The experimental group, which engaged in the PBL-CAD approach, demonstrated a substantial improvement in post-test performance compared to the control group, which followed traditional instructional methods. These findings are consistent with previous research that highlights the role of PBL in fostering active learning, critical thinking, and deeper understanding of technical concepts (Goshu & Ridwan, 2024).

The notable improvement observed in the experimental group can be attributed to several key factors. First, the use of CAD tools allowed students to visualize complex structures in an interactive and precise digital environment, thereby enhancing spatial reasoning and design accuracy. As highlighted by Tan & Li (2024), CAD facilitates iterative learning and provides immediate feedback, which are essential for mastering drawing conventions in technical disciplines such as architecture and engineering.

Second, the project-based model offered students authentic, real-world tasks that closely mirrored industry practices. By engaging in collaborative design projects, students developed critical skills in problem-solving, communication, and project management core competencies required in vocational education. These findings corroborate those of Prabhu et al. (2024), who noted that integrating PBL with CAD enhances student motivation and practical competence.

In contrast, the control group showed only moderate improvement, which may be attributed to the limitations of teacher centered approaches that emphasize procedural repetition rather than fostering a deeper conceptual understanding. Traditional methods may fail to fully engage students and address the demands of a technology-driven workforce, as indicated by similar studies (Hazrat et al., 2023; Hakiki et al., 2024).

Moreover, the substantial effect size (Cohen's d = 2.97) observed in the experimental group underscores the educational significance of the PBL CAD intervention. This suggests that the integration of PBL with CAD not only improves academic performance

but also aligns students' learning with the evolving demands of modern industry, thereby contributing to the broader objectives of 21st century vocational education.

Despite these encouraging results, several limitations should be acknowledged. The study was conducted in a single vocational school, which may limit the generalizability of the findings. Furthermore, while the focus of this research was on cognitive outcomes (i.e., technical drawing ability), future studies should investigate additional affective and behavioral outcomes, such as student engagement, self efficacy and long term skill retention.

In conclusion, the integration of Project Based Learning with CAD software proves to be an effective pedagogical approach for enhancing technical competencies in vocational education. Not only does it improve students' drawing skills, but it also promotes collaboration, digital literacy and prepares students for professional success in the rapidly evolving fields of construction and design.

CONCLUSION

This study concludes that integrating Project Based Learning (PBL) with Computer Aided Design (CAD) software is an effective instructional strategy for enhancing technical drawing skills among vocational high school students. The empirical results show a statistically significant improvement in the drawing competencies of students who participated in the PBL CAD intervention compared to those taught using conventional methods. The integration of authentic design tasks and digital tools contributed not only to cognitive skill development but also fostered engagement, collaboration, and real-world problem solving abilities. These findings support the growing body of literature advocating for the application of constructivist and technology-enhanced approaches in vocational education. By aligning instructional practices with industry-relevant tools and project-oriented learning, educators can better prepare students for the professional demands of the design and construction fields. Future studies should explore the long-term impact of PBL CAD models on workplace readiness and consider implementation across various vocational disciplines and educational contexts. Additionally, incorporating qualitative measures may provide deeper insights into student experiences and motivational shifts during the learning process. Ultimately, this research reinforces the importance of

pedagogical innovation in vocational training, especially in an era where digital competence and applied problem-solving are critical to student success.

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