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The Effectiveness of the Project-Based Learning Model Based on Autodesk Inventor on Students' Learning Outcomes in the Manufacturing Engineering Drawing Subject at SMK Negeri 1 Padang

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Abstract

Project-based learning supported by digital design technology has become increasingly relevant in vocational education; however, empirical evidence on its application with Autodesk Inventor in Manufacturing Engineering Drawing remains limited. This study aims to evaluate the effectiveness of the Autodesk Inventor-based Project-Based Learning model in improving students' learning outcomes in the Manufacturing Engineering Drawing subject at SMK Negeri 1 Padang. A quantitative approach with a quasi-experimental non-equivalent control group design was employed. The participants consisted of 40 Grade XI Mechanical Engineering students selected through purposive sampling and divided into an experimental class and a control class. Data were collected through pretest, posttest, and documentation and were analyzed using descriptive statistics, the Shapiro–Wilk normality test, Levene's homogeneity test, and paired sample t-test with the assistance of SPSS. The findings indicate that both classes experienced significant improvement; however, the experimental class achieved a higher mean score increase than the control

class. The experimental class improved from 48.30 to 66.85, whereas the control class improved from 44.25 to 57.55. The posttest comparison showed a 16.15% difference in favor of the experimental class. The study concludes that Autodesk Inventor-based Project-Based Learning is effective in improving students' learning outcomes in vocational technical drawing. These findings provide practical implications for vocational education by highlighting the importance of integrating project-based pedagogical models with digital design technology to support more effective learning in Manufacturing Engineering Drawing.

Keywords: Autodesk Inventor; Project-Based Learning; Learning Outcomes; Manufacturing Engineering Drawing; Vocational Education

INTRODUCTION

Vocational education plays an important role in preparing students to enter the workforce with specific knowledge, skills, and professional attitudes (Huang, 2025; Perić et al., 2020; Sulaiman & Ambotang, 2017). At the international level, technical and vocational education and training is increasingly directed toward strengthening employability, digital competence, and readiness for technological transformation in industry (Ismail & Hassan, 2019; Kamaruzaman et al., 2025; Utami et al., 2025). UNESCO emphasizes that vocational education must support students in developing relevant skills for productive employment, decent work, and adaptation to digital and green economic transitions (UNESCO, 2022). This condition indicates that vocational schools are required not only to provide theoretical knowledge but also to develop practical competencies that are closely related to industrial needs.

In Indonesia, vocational education has a strategic position in preparing middle-level skilled workers (Ismail & Hassan, 2019; Kamaruzaman et al., 2025; Utami et al., 2025). Law Number 20 of 2003 concerning the National Education System states that vocational education is secondary education that prepares students to work in specific fields. This is also in line with Government Regulation Number 29 of 1990, which emphasizes that vocational education prioritizes the development of students' abilities to enter the workforce and develop professional attitudes. Therefore, learning in vocational schools should be designed to strengthen students' mastery of concepts, technical skills, creativity, and problem-solving abilities in accordance with the demands of the industrial world.

One of the important subjects in vocational education, especially in mechanical engineering expertise programs, is Manufacturing Engineering Drawing (Gao et al., 2021; Inderanata & Sukardi, 2023; Ssenyonga, 2021). This subject requires students to understand technical drawing concepts, read two-dimensional drawings, imagine three-dimensional objects, and create manufacturing designs using appropriate standards and procedures. However, in practice, students often experience difficulties in understanding the relationship between 2D drawings and 3D models. This difficulty becomes more serious when learning is still dominated by conventional methods, where students only receive explanations from teachers and rely on printed books without sufficient practical and visual learning experiences.

The initial observation conducted at SMK Negeri 1 Padang showed that the learning process in Manufacturing Engineering Drawing still tended to be teacher-centered (Fitra et al., 2024; Ridwan et al., 2025; Wahyu et al., 2025). Students were mostly passive, rarely asked questions, and only listened to the teacher's explanation. The data from the final semester examination also indicated that many students had not achieved the minimum mastery criteria. In class XI TPM A and XI TPM B, a considerable number of students scored below the minimum mastery criterion of 75. This condition shows that the learning outcomes of students in Manufacturing Engineering Drawing still need to be improved through a more active, contextual, and technology-based learning model.

The researcher views that this problem is closely related to the learning model used in the classroom. Conventional learning tends to limit students' opportunities to explore, discuss, design, and produce works independently or collaboratively. According to constructivist learning theory, knowledge is not passively received by students but actively constructed through experience, interaction, and involvement in meaningful activities (Vygotsky, 1978). In this context, learning should provide space for students to build their understanding through direct practice, collaboration, and problem-solving activities related to real situations.

Project Based Learning is considered relevant to overcome these learning problems because it places students as active learners who are involved in completing real projects. Through this model, students do not only learn concepts theoretically but also apply them in producing a certain product or solution. Project Based Learning encourages students to plan, investigate, design, collaborate, and evaluate their work. This model is in accordance

with the needs of vocational education because it connects learning materials with practical activities and real industrial contexts. Previous studies have shown that project-based learning can improve students' understanding, motivation, creativity, collaboration, and learning outcomes (Adawiah & Maulida, 2024).

The integration of Autodesk Inventor into Project Based Learning is also important because Manufacturing Engineering Drawing requires students to master computer-aided design skills. Autodesk Inventor allows students to visualize objects in three-dimensional form, understand the structure of components, and create technical designs more accurately. The use of CAD-based learning media can help students bridge the gap between abstract drawing concepts and real product visualization. In vocational learning, digital design applications such as Autodesk Inventor are relevant because they support students in developing competencies that are needed in the manufacturing and mechanical engineering industries (Abdulrasool & Mishra, 2009; Belan, 2024; Dzhumaevich, 2020).

Several previous studies have discussed the effectiveness of Project Based Learning in improving student learning outcomes. For example, Adawiah and Maulida (2024) found that Project Based Learning had a positive effect on students' cognitive learning outcomes. Other studies also show that project-based learning can increase student engagement and make learning more productive and meaningful (Athaya et al., 2024; Muhammad Abdi Nugraha, Budi Syahri, Waskito, 2022). However, most previous studies have focused on general subjects or have not specifically examined the integration of Project Based Learning with Autodesk Inventor in Manufacturing Engineering Drawing. The gap in this study lies in the limited empirical evidence regarding the effectiveness of Autodesk Inventor-based Project Based Learning in improving students' learning outcomes in the context of vocational manufacturing drawing subjects at SMK Negeri 1 Padang.

Based on these issues, this study focuses on examining the effectiveness of the Autodesk Inventor-based Project Based Learning model on students' learning outcomes in the Manufacturing Engineering Drawing subject at SMK Negeri 1 Padang. This research is expected to provide empirical evidence regarding the use of project-based and technology-based learning models in vocational education. In addition, the results of this study are expected to contribute to the development of more innovative, practical, and industry-relevant learning strategies, especially in improving students' understanding of technical drawing concepts and their ability to apply design skills using digital technology.

METHODS

This study employed a quantitative approach because the data were numerical and analyzed using statistical procedures. Quantitative research is appropriate when a study aims to measure variables objectively and examine differences or effects between groups (Creswell, 2014; Sugiyono, 2019). The research design used was a quasi-experimental method with a non-equivalent control group design, involving one experimental class and one control class. This design was selected because the researcher could not randomly assign students to the experimental and control groups, but both groups were given a pretest and posttest to determine changes in learning outcomes after treatment (Gall et al., 2003). The experimental class was taught using the Project Based Learning model based on Autodesk Inventor, while the control class was taught using a conventional learning model. The study was conducted at SMK Negeri 1 Padang in the odd semester of the 2025 academic year. The population consisted of grade XI students of the Mechanical Engineering Program, while the sample was selected through purposive sampling based on the researcher's consideration and discussion with the Manufacturing Engineering Drawing teacher. The sample consisted of two classes: XI TP A as the experimental class and XI TP B as the control class, with a total of 40 students.

The data collection techniques used in this study were tests and documentation. The test instrument consisted of 30 multiple-choice questions administered as a pretest and posttest to measure students' cognitive learning outcomes in the Manufacturing Engineering Drawing subject. The questions were developed based on the learning indicators related to CAD software, especially Autodesk Inventor, including the ability to explain, identify, and apply drawing commands in 2D and 3D design. The instrument validity was examined through expert judgment involving a lecturer from the Department of Mechanical Engineering, Universitas Negeri Padang, and a Manufacturing Engineering Drawing teacher at SMK Negeri 1 Padang. The content validity was calculated using Aiken's V index, in which the obtained scores indicated that the instrument was feasible to use (Sugiyono, 2016). The research procedure consisted of preparation, implementation, and final stages. In the preparation stage, the researcher conducted an initial survey, determined the sample classes, and prepared learning devices. In the implementation stage, students were given a pretest, followed by treatment in the experimental and control classes, and then a posttest. The collected data were analyzed using descriptive and inferential statistics with SPSS version 20.0. The analysis included the Shapiro-Wilk

normality test, Levene's homogeneity test, and t-test at a significance level of 0.05 to determine whether the Autodesk Inventor-based Project Based Learning model had a significant effect on students' learning outcomes.

RESULTS

The results of this study are presented based on the prerequisite tests and hypothesis testing used to determine the effectiveness of the Autodesk Inventor-based Project Based Learning model on students' learning outcomes in the Manufacturing Engineering Drawing subject. The analysis included the normality test, homogeneity test, and paired sample t-test. These tests were conducted to ensure that the data met the statistical requirements before drawing conclusions regarding the effect of the learning model.

1. Result 1: Normality Test

The normality test was conducted to determine whether the pretest and posttest scores of the control and experimental classes were normally distributed. The test was carried out using the Shapiro-Wilk method because the number of students in each class was less than 50. The decision criterion was that if the significance value was greater than 0.05, the data were considered normally distributed.

Table 1. Results of the Normality Test of Students' Learning Outcomes

Variable	Class	Shapiro-Wilk Statistic	df	Sig.
Pretest	Control	0.905	20	0.052
Posttest	Control	0.964	20	0.635
Pretest	Experimental	0.956	20	0.466
Posttest	Experimental	0.921	20	0.106

Based on Table 1, all significance values in the Shapiro-Wilk test were greater than 0.05. The pretest score of the control class obtained a significance value of 0.052, while the posttest score obtained 0.635. In the experimental class, the pretest score obtained a significance value of 0.466, and the posttest score obtained 0.106. Therefore, it can be concluded that the learning outcome data in both the control and experimental classes were normally distributed. Thus, the data met the requirement for further statistical testing using the t-test.

2. Result 2: Homogeneity Test

The homogeneity test was conducted to determine whether the data from the control and experimental classes had the same or homogeneous variance. This test was carried out using Levene's test with the help of SPSS. The decision criterion was that if the significance value was greater than 0.05, the data variance was considered homogeneous.

Table 2. Results of the Homogeneity Test of Students' Learning Outcomes

Variable	Test Basis	Levene Statistic	df1	df2	Sig.
Learning Outcomes using Autodesk Inventor	Based on Mean	0.378	1	78	0.541
Learning Outcomes using Autodesk Inventor	Based on Median	0.367	1	78	0.546
Learning Outcomes using Autodesk Inventor	Based on Median and Adjusted df	0.367	1	77.47	0.546
Learning Outcomes using Autodesk Inventor	Based on Trimmed Mean	0.383	1	78	0.538

Table 2 shows that the significance value based on the mean was 0.541. This value was greater than 0.05, indicating that the variance of the data from the control and experimental classes was homogeneous. Therefore, the data fulfilled the assumption of homogeneity and could be analyzed further using the t-test.

3. Result 3: Hypothesis Testing

Hypothesis testing was conducted to determine whether there was a significant difference between students' pretest and posttest scores after the learning treatment. Since the data were normally distributed and homogeneous, the paired sample t-test was used. The decision criterion was that if the significance value was less than 0.05, there was a significant difference between the pretest and posttest scores.

Table 3. Results of the Paired Sample T-Test of Students' Learning Outcomes

Pair	Mean Difference	Std. Deviation	Std. Error Mean	95% CI Lower	95% CI Upper	t	df	Sig. (2-tailed)
Pretest Control – Posttest Control	-13.300	18.711	4.184	-22.057	-4.543	-3.179	19	0.005
Pretest Experimental – Posttest Experimental	-12.550	20.098	4.494	-21.956	-3.144	-2.793	19	0.012

Based on Table 3, the significance value of the control class was 0.005, which was lower than 0.05. This result indicates that there was a significant difference between the pretest and posttest scores in the control class. Meanwhile, the experimental class obtained a significance value of 0.012, which was also lower than 0.05. This finding indicates that

there was a significant difference between the pretest and posttest scores after the implementation of the Autodesk Inventor-based Project Based Learning model.

These results show that the Autodesk Inventor-based Project Based Learning model had a significant effect on students' learning outcomes in the Manufacturing Engineering Drawing subject. The implementation of this model helped students understand CAD concepts, identify drawing commands, and apply 2D and 3D design procedures more effectively. Therefore, the hypothesis stating that there is a positive and significant effect of the Autodesk Inventor-based Project Based Learning model on students' learning outcomes in Manufacturing Engineering Drawing at SMK Negeri 1 Padang is accepted.

DISCUSSION

This study aimed to examine the effectiveness of the Autodesk Inventor-based Project Based Learning model in improving students' learning outcomes in the Manufacturing Engineering Drawing subject at SMK Negeri 1 Padang. The findings showed that both the control class and the experimental class experienced an increase in learning outcomes after the learning process. However, the increase in the experimental class was higher than that of the control class. The control class obtained a pretest mean score of 44.25 and a posttest mean score of 57.55, with an improvement of 30.06%. Meanwhile, the experimental class obtained a pretest mean score of 48.30 and a posttest mean score of 66.85, with an improvement of 37.96%. The difference in posttest achievement between the two classes was 16.15%, indicating that students taught using the Autodesk Inventor-based Project Based Learning model achieved better learning outcomes than students taught using the conventional learning model.

The results of the prerequisite tests showed that the data were suitable for further statistical analysis. The Shapiro-Wilk normality test indicated that all pretest and posttest data in both classes were normally distributed, with significance values greater than 0.05. The homogeneity test using Levene's test also showed a significance value of 0.541, which was greater than 0.05, indicating that the data had homogeneous variance. These results confirmed that the data met the assumptions required for hypothesis testing. Based on the paired sample t-test, the control class obtained a significance value of 0.005, while the experimental class obtained a significance value of 0.012. Both values were lower than 0.05,

meaning that there was a significant difference between the pretest and posttest scores in each class. However, the higher posttest mean score and greater percentage improvement in the experimental class demonstrated that the Autodesk Inventor-based Project Based Learning model was more effective in improving students' learning outcomes (Agalya & Seneviratne, 2024).

The improvement in the experimental class can be interpreted as the result of students' active involvement in project-based activities. Through Project Based Learning, students were not only asked to understand concepts theoretically but also encouraged to apply them in practical design activities using Autodesk Inventor. This learning process allowed students to observe, design, modify, and evaluate 2D and 3D technical drawings more concretely (Saralar-Aras & Aınsworth, 2025; Younes et al., 2024) . The use of Autodesk Inventor helped students visualize manufacturing drawing concepts that are often difficult to understand through conventional explanation alone. Therefore, the integration of digital design software into project-based learning made the learning process more contextual, practical, and relevant to the needs of vocational education.

These findings are in line with the constructivist view that students build knowledge actively through experience, interaction, and meaningful activities. In the context of vocational learning, Project Based Learning provides opportunities for students to develop understanding through direct practice and problem solving. The results of this study also support the findings of Hamidah & Citra (2021), who found that the Project Based Learning model had a significant effect on students' learning outcomes at SMK Negeri 7 Makassar, with a significance value lower than 0.05. This consistency shows that Project Based Learning is an effective learning model for improving students' achievement, especially in subjects that require active participation, technical skills, and practical application.

Theoretically, this study strengthens the relevance of Project Based Learning in vocational education, particularly in Manufacturing Engineering Drawing (Chang et al., 2022; Gomes et al., 2025; Ridwan et al., 2025). The integration of Autodesk Inventor adds novelty because it combines project-based learning with computer-aided design technology. This combination supports students in connecting technical drawing theory with digital manufacturing design practice. Practically, the findings imply that teachers can use Autodesk Inventor-based Project Based Learning as an alternative learning model to

improve students' understanding, motivation, and technical drawing skills. This model can also help schools prepare students to be more familiar with digital tools commonly used in the manufacturing industry.

However, this study has several limitations. First, the sample was limited to two classes of grade XI Mechanical Engineering students at SMK Negeri 1 Padang, so the findings cannot be generalized to all vocational schools. Second, the study focused mainly on cognitive learning outcomes measured through pretest and posttest scores, while students' practical skills, creativity, collaboration, and project quality were not analyzed in depth. Third, several external factors, such as students' prior experience with Autodesk Inventor, learning motivation, availability of computers, and differences in learning pace, may have influenced the results. Therefore, future research is recommended to involve a larger sample, include more vocational schools, and examine not only cognitive outcomes but also practical skills and student project performance.

CONCLUSION

This study concludes that the Autodesk Inventor-based Project Based Learning model had a positive and significant effect on students' learning outcomes in the Manufacturing Engineering Drawing subject at SMK Negeri 1 Padang. The results of the paired sample t-test showed that both the control class and the experimental class experienced significant improvement after the learning process. The control class obtained a significance value of 0.005, while the experimental class obtained a significance value of 0.012. Since both values were lower than 0.05, it can be concluded that there was a significant difference between the pretest and posttest scores in both classes.

Although both classes showed significant improvement, the experimental class demonstrated better learning achievement based on the mean scores. The mean score of the control class increased from 44.25 in the pretest to 57.55 in the posttest, while the mean score of the experimental class increased from 48.30 in the pretest to 66.85 in the posttest. The comparison of posttest mean scores showed a difference of 16.15% in favor of the experimental class. These findings indicate that the implementation of the Autodesk Inventor-based Project Based Learning model was more effective than conventional learning in improving students' understanding of Manufacturing Engineering Drawing concepts. Therefore, this model can be used as an alternative learning strategy in vocational

education, especially in subjects that require technical drawing skills, digital design competence, and project-based practical activities. Future research is recommended to involve a larger sample, different vocational schools, and additional assessment aspects such as practical skills, creativity, collaboration, and the quality of students' design projects.

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