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Comparative Study of AI-Based and Direct Instruction on Grinding Machining Learning Outcomes at SMK Turen

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ABSTRACT

This study aimed to determine the effectiveness of ChatGPT, an Artificial Intelligence (AI)-based learning tool, on student learning outcomes in the subject of Grinding Machining Engineering at the vocational high school level. The research employed a quantitative approach using a quasi-experimental design with a nonequivalent two-group pretest–posttest model, comparing an experimental group taught using ChatGPT-assisted learning (Group X1) and a control group taught using Direct Instruction (Group X2). The subjects of this study were 50 students of class X in the Grinding Machining Engineering program at SMK Turen, divided into two groups of 25 students each. Data collection was conducted using objective multiple-choice tests consisting of 20 items that had passed validity and reliability testing with a Cronbach's Alpha value of 0.745. Data analysis techniques included descriptive statistics, normality test, homogeneity test, Independent Sample T-Test, and N-Gain analysis using IBM SPSS Statistics version 26. The results showed that the average posttest score in the ChatGPT-assisted (AI-based) learning group was higher than that of the Direct Instruction group. The Independent Sample T-Test showed a significance value of <0.001, indicating a significant difference between the two instructional approaches. Furthermore, the N-Gain analysis showed that the ChatGPT-assisted learning group obtained a higher average score (0.615) compared to the Direct Instruction group (0.453), both categorized as moderate improvement. Therefore, ChatGPT-assisted learning was proven to be more effective in improving student learning outcomes in Grinding Machining Engineering subjects because it provides a more interactive, adaptive, and flexible learning experience.

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1. INTRODUCTION

Vocational education plays a strategic role in developing competent, adaptive, and work-ready human resources[1]. Vocational High Schools (SMK), including SMK Turen, are expected to produce graduates who possess not only theoretical understanding but also practical and applicable technical skills. One of the essential competencies in the field of Mechanical Engineering is Grinding Machining Engineering, which requires students to master both conceptual knowledge and practical abilities [2]. The effectiveness of learning in this subject is strongly influenced by the instructional approach implemented by teachers in delivering the learning materials [3].

Instructional approaches function as important tools for facilitating the delivery of learning materials, enhancing student engagement, creating a conducive learning environment, and improving students' comprehension of the subject matter [4]. However, preliminary observations conducted at SMK Turen indicated that the learning process in Grinding Machining Engineering is still predominantly conducted through the Direct Instruction approach, with textbooks serving as the primary learning resource [5]. This teacher-centered approach tends to limit students' active participation, resulting in lower motivation and reduced involvement during the learning process. Consequently, students' conceptual understanding and overall learning outcomes have not yet reached optimal levels [6].

The rapid advancement of information technology, particularly Artificial Intelligence (AI), has created significant opportunities for innovation in the educational sector. Among the various AI applications available, ChatGPT was selected for this study because it is freely accessible, supports natural-language interaction, and can generate adaptive explanations, examples, and instant feedback tailored to students' questions during the learning process [7]. Furthermore, this technology provides instant feedback, interactive learning exercises, and opportunities for independent learning that can be accessed anytime and anywhere [8]. In contrast to Direct Instruction, which is generally static and teacher-centered, ChatGPT-assisted learning has the potential to enhance student engagement, learning motivation, and comprehension of instructional materials [9].

In this study, AI-based learning specifically refers to instructional activities supported by ChatGPT, used to deliver adaptive and interactive explanations of instructional materials and to respond to students' questions during the learning process [2]. Meanwhile, Direct Instruction refers to a conventional teacher-centered learning approach in which instructional materials are delivered directly by the teacher using textbooks as the primary learning resource. Students' learning outcomes in this study are measured through test scores that reflect students' mastery of Grinding Machining Engineering materials [10].

Previous studies have demonstrated that the implementation of digital technology in education can positively improve students' motivation and academic achievement.

Nevertheless, studies specifically examining the comparative effectiveness of ChatGPT-assisted learning and Direct Instruction in Grinding Machining Engineering subjects at the vocational high school level remain limited [11]. In addition, the implementation of AI-based learning is influenced by several factors, including the availability of technological infrastructure, students' digital literacy, and the equality of students' initial competencies, all of which constitute important considerations in this study [12].

Based on these issues, this study aims to analyze the differences in learning outcomes between students taught using ChatGPT-assisted learning and those taught using Direct Instruction in Grinding Machining Engineering subjects at SMK Turen. This study assumes that both groups possess equivalent initial abilities prior to the treatment, so that any differences in learning outcomes may be attributed to the different instructional approaches employed [13]. Therefore, the research hypothesis states that there is a significant difference in learning outcomes between students who learn through ChatGPT-assisted learning and those who learn through Direct Instruction.

The findings of this study are expected to contribute theoretically to the development of educational technology research in vocational education and practically to assist teachers and schools in selecting more innovative, interactive, and effective instructional approaches to improve the quality of learning in Grinding Machining Engineering subjects at vocational high schools.

2. RESEARCH METHOD

This study employed a quantitative approach using a quasi-experimental design with a nonequivalent two-group pretest–posttest model. This research design was intended to examine the effect of ChatGPT-assisted, Artificial Intelligence (AI)-based learning on students' learning outcomes by comparing an experimental group (taught using ChatGPT-assisted learning) and a control group (taught using Direct Instruction). The study was conducted during the second semester of the 2024/2025 academic year at SMK Turen.

The research subjects consisted of 50 tenth-grade students from the Welding Engineering program, divided into two groups of 25 students each: an experimental group (X1) taught using ChatGPT-assisted learning and a control group (X2) taught using Direct Instruction. The sampling technique applied in this study was total sampling, in which the entire eligible population was selected as the research sample due to the relatively limited number of participants and its suitability with the objectives of the study.

The research procedure began with the administration of a pretest to both groups to determine students' initial abilities in technical drawing materials. Subsequently, the experimental group (X1) received learning supported by ChatGPT, which was used to present learning content, explain concepts, and respond to students' questions in a more interactive, adaptive, and communicative manner, while the control group (X2) received conventional Direct Instruction using textbooks. After the treatment was completed, both

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groups were given a posttest to measure the improvement in learning outcomes. The assessment focused on students' cognitive aspects, including the ability to identify line types, understand technical drawing symbols, comprehend dimensioning rules, and read as well as interpret working drawings.

The research instrument consisted of 20 multiple-choice objective test items developed based on the learning achievement indicators. Prior to its implementation, the instrument was tested for validity and reliability to ensure its appropriateness for data collection [14]. Reliability testing was conducted using the Cronbach's Alpha method with the assistance of IBM SPSS Statistics.

Table 1. Results of Instrument Reliability Test

Cronbach's Alpha	N of Item's
.745	20

Based on the reliability testing results, the instrument obtained a Cronbach's Alpha value of 0.745, indicating that the instrument was reliable because the reliability coefficient exceeded 0.70. Therefore, the research instrument was considered appropriate for measuring students' learning outcomes in both the pretest and posttest activities. Data analysis techniques were carried out using descriptive and inferential statistical analyses with the assistance of IBM SPSS Statistics. Descriptive statistical analysis was used to determine the mean score, minimum score, maximum score, and standard deviation of the pretest and posttest results.

Furthermore, a normality test was conducted as a prerequisite for parametric statistical analysis. Hypothesis testing was performed using the Independent Sample T-Test to compare the learning outcomes of the experimental (ChatGPT-assisted) and control (Direct Instruction) groups. In addition, N-Gain analysis was employed to identify the effectiveness level of the improvement in students' learning outcomes in each group. The research procedure is presented in the form of a flowchart in Figure 1.

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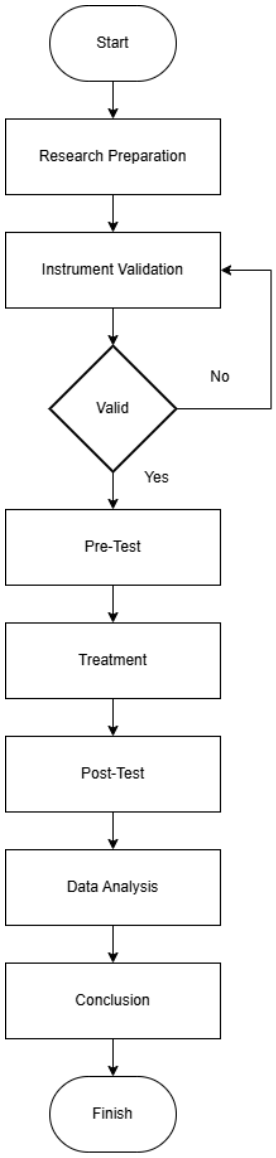

Figure 1. Flowchart

3. RESULTS AND DISCUSSION

This section presents the analysis of vocational high school students' learning outcomes in the Technical Drawing subject obtained from the pretest and posttest scores of both the experimental (X1, ChatGPT-assisted) and control (X2, Direct Instruction) groups. The research findings are organized according to the sequence of the research flowchart, including data description, prerequisite tests (descriptive analysis, N-Gain, normality, homogeneity, and Independent Sample T-Test), and hypothesis testing regarding the effect of the learning approach on the improvement of students' learning outcomes.

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Table 2. Descriptive Analysis

	Descriptive Statistic				
	N	**Minimum**	**Maximum**	**Mean**	**Std. Dev**
Pre-Test (X1)	25	50	65	55,1667	5,33
Post-Test (X1)	25	60	95	78,33	9,76
Pre-Test (X1)	25	45	60	52	4,1
Post-Test (X1)	25	60	85	67,83	5,52
Valid N	25				

Based on the results of the descriptive statistical analysis presented in the table above, the research sample consisted of 25 students in each group. In Group X1 (ChatGPT-assisted), the pretest scores had a mean of 55.17, with a minimum score of 50, a maximum score of 65, and a standard deviation of 5.33. After receiving ChatGPT-assisted learning, the posttest scores showed an improvement, with a mean score of 78.33, a minimum score of 60, a maximum score of 95, and a standard deviation of 9.76.

Meanwhile, Group X2 obtained a pretest mean score of 52.00, with a minimum score of 45, a maximum score of 60, and a standard deviation of 4.10. Following the treatment, the posttest scores increased to a mean of 67.83, with a minimum score of 60, a maximum score of 85, and a standard deviation of 5.52.

Based on these findings, it can be concluded that there was an increase in the average student learning outcomes after the implementation of Artificial Intelligence (AI)-based learning. This indicates that the ChatGPT-assisted learning approach was effective in helping students understand grinding machining technique more effectively compared to their understanding before the treatment was administered.

Table 3. N-Gain Analysis

Group	**N**	***Minimum***	***Maximum***	***Mean***	***Std. Deviation***	**Category**
AI Based	25	0,350	0,861	0,615	0,148	Moderate
Direct Instruction	25	0,218	0,750	0,453	0,170	Moderate
Valid N (*listwise*)	25					

Based on the N-Gain analysis results, the Artificial Intelligence (AI)-based learning group obtained an average N-Gain score of 0.615, which falls into the moderate category, while the Direct Instruction group achieved an average N-Gain score of 0.453, also categorized as moderate. These findings indicate that both instructional approaches were able to improve students' learning outcomes; however, AI-based learning demonstrated a higher level of improvement compared to the Direct Instruction approach.

The difference in the average N-Gain scores suggests that that ChatGPT-assisted learning was more effective in assisting students to understand Mechanical grinding materials through a more interactive and adaptive learning process [15].

Tabel 4. Tests of Normality

	Class	Kolmogorof-Smirnov[a]			shapiro-wilk		
		Statistic	df	sig.	statistics	df	sig.
Result	Pre-Test (X1)	.119	25	.200*	.967	25	.560
	Post-Test (X1)	.116	25	.200*	.969	25	.621
	Pre-Test (X2)	.104	25	.200*	.967	25	.575
	Post-Test (X2)	.107	25	.200*	.977	25	.814

Based on the normality test results presented in the *Tests of Normality* table, the significance values (Sig.) for both the pretest and posttest data in Groups X1 and X2 were found to be greater than 0.05 [16]. In the Shapiro–Wilk test, the significance values obtained were 0.560 for PreTest (X1), 0.621 for PostTest (X1), 0.575 for PreTest (X2), and 0.814 for PostTest (X2). Since all significance values exceeded 0.05, the research data can be concluded to be normally distributed.

Furthermore, the Kolmogorov–Smirnov test also produced significance values of 0.200 for all data groups, further confirming that the data met the assumption of normality [17]. Therefore, the research data were considered suitable for parametric statistical analysis and could be further analyzed through hypothesis testing using the Independent Sample T-Test.

Tabel 5. Homogeneity Test

		Levene Statistic	*df1*	*df2*	*Sig.*
Result	*Based on Mean*	1,257	3	96	0,294
	Based on Median	1,06	3	96	0,37
	Based on Median and with adjusted df	1,06	3	91	0,37
	Based on Trimmed Mean	1,253	3	96	0,295

Based on the results of the homogeneity test presented in the *Test of Homogeneity of Variance* table, the significance value (Sig.) based on the mean was 0.294. Since this value is greater than 0.05, it can be concluded that the variance of the research data was homogeneous. This result indicates that the data across groups had a relatively similar level of variability.Furthermore, the results obtained from other measurement bases, including

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Median, Median with adjusted degrees of freedom, and Trimmed Mean, also showed significance values greater than 0.05 [18]. Therefore, all research data satisfied the assumption of homogeneity and were considered appropriate for parametric statistical analysis, allowing the study to proceed to the hypothesis testing stage.

Tabel 6. Independent Sample T Test

		Levene's test for equality of variances						
		F	Sig.	t	df	Sig. (2-Tailed)	Mean difference	Std. Error Differensce
Result	Equal variances assumed	2,744	0,104	5,696	48	<0,001	12,800	2,247
	Equal variances not assumed	0	0	5,696	44,378	<0,001	12,800	2,247

Based on the results of the Independent Sample T-Test presented in the table above, the significance value obtained from Levene's Test was 0.104. Since the significance value was greater than 0.05, the data were considered homogeneous; therefore, the interpretation of the test results was based on the *Equal Variances Assumed* row.

The test results revealed a significance value (Sig. 2-tailed) of < 0.001, which was lower than 0.05. This finding indicates that there was a statistically significant difference in students' learning outcomes between the two groups being compared. In addition, the calculated t-value was 5.696, with a mean difference of 12.80000, indicating an improvement in students' learning outcomes following the implementation of ChatGPT-assisted learning. Therefore, it can be concluded that the use of ChatGPT-assisted had a significant effect on students' learning outcomes in the Grinding Machining Engineering subject.

4. CONCLUSION

Based on the results of this study, the implementation of ChatGPT-assisted, Artificial Intelligence (AI)-based learning in the Grinding Machining Engineering subject was proven to have a positive effect on students' learning outcomes. This finding was indicated by the increase in the average posttest scores compared to the pretest scores, with the ChatGPT-assisted group outperforming the Direct Instruction group. Furthermore, the statistical test results demonstrated that the research data were normally distributed and homogeneous, thereby fulfilling the requirements for hypothesis testing using the Independent Sample T-Test.

The hypothesis testing results revealed a significance value (Sig. 2-tailed) of < 0.05, indicating a significant difference in learning outcomes between the ChatGPT-assisted learning group and the Direct Instruction group. In addition, the N-Gain analysis showed that the ChatGPT-assisted learning group achieved a higher improvement score compared to the Direct Instruction group. These findings suggest that ChatGPT-assisted learning was

able to provide a more interactive, flexible, and adaptive learning experience, enabling students to understand Grinding Machining Engineering materials more effectively than conventional teacher-centered learning approaches.

Theoretically, these findings extend the existing literature on adaptive and personalized learning by providing empirical evidence, specific to a generative-AI conversational tool (ChatGPT), within a vocational technical-skills context that has received limited prior attention. Practically, the results suggest that vocational schools can integrate ChatGPT as a low-cost, readily accessible supplementary tool to support concept explanation and formative feedback in technical subjects, provided teachers receive guidance on designing structured AI-assisted activities and schools ensure adequate device and internet access. Future research is encouraged to replicate this study across larger and more diverse samples, longer instructional periods, and additional AI platforms to strengthen the generalizability of these conclusions.

The findings of this study are supported by the research conducted by Zakariyah [18]. which stated that AI-based adaptive learning can improve students' learning outcomes through more personalized and interactive instructional delivery. Therefore, ChatGPT-assisted, Artificial Intelligence (AI)-based learning can be considered an effective instructional innovation for improving students' learning outcomes in the Grinding Machining Engineering subject.

This study has several limitations. The sample was limited to Grinding Machining Engineering students at a single vocational school (SMK Turen), restricting the generalizability of the findings. The pre-experimental design also lacked an independent control group, so factors such as maturation or testing effects cannot be fully ruled out. In addition, learning outcomes were measured only through a cognitive multiple-choice test, without assessing students' practical grinding machining skills. Future studies should involve larger, multi-school samples, a genuine control group, and performance-based assessments for a more comprehensive evaluation.

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