

APPLICATION OF AUGMENTED REALITY-BASED LEARNING MEDIA TO IMPROVE LEARNING OUTCOMES REGARDING THE FUNCTION OF MACHINE PARTS FOR STUDENTS OF THE MECHANICAL ENGINEERING EXPERTISE PROGRAM

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ABSTRACT

This study was conducted to determine the effectiveness of the use of Augmented Reality (AR)-based learning media in improving student learning outcomes on the function of milling machine components in the Mechanical Engineering Expertise Program. A quantitative approach was used with a quasi-experimental method with a Pretest-Posttest Design of Two Groups. This study involved two class XI majoring in mechanical engineering at SMA Negeri 1 Semarang as participants. Of the total number of students, 35 students were included in the experimental group, while 35 other students were included in the control group. Data were collected through tests, observations, and documentation. Prior to implementation, the research instruments were examined through expert validation using Aiken's V, Content Validity Index (CVI), and Intraclass Correlation Coefficient (ICC). The data were then analyzed using descriptive statistics, a Shapiro-Wilk normality test, a Levene homogeneity test, a one-way independent sample t-test, and an N-Gain analysis. The results of the data analysis showed differences in learning outcomes after the two groups received different learning treatments. Students in the experimental group who received learning supported by AR-based media achieved an average posttest score of 84.63, while the control group obtained an average score of 70.49. Hypothesis testing resulted in a t-value of 25.063, which is higher than the critical value of 1.668 at a significance level of 0.05. The test results showed a statistically significant difference in learning outcomes between the experimental group and the control group. The experimental group showed higher average learning outcomes than the control group. The improvement in learning outcomes was also reflected in the N-Gain score, with the experimental group obtaining a score of 0.622, which was categorized as moderate, while the control group obtained a score of 0.286, which was categorized as low. Therefore, the use of AR-based learning media showed a positive contribution in improving student learning outcomes in understanding the function of milling machine components.

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INTRODUCTION

Vocational education aims to develop students' theoretical knowledge and practical skills according to

the needs of the world of work. In mechanical engineering, milling is an important field because students must understand how machines work. components and understand their functions before taking out machining operations. When these components are explained mainly through verbal descriptions or static drawings, students may find it difficult to imagine their three-dimensional characteristics. Recent studies in vocational education show that digital and immersive media can provide a more concrete learning experience and support the understanding of technical subject matter (Supriyanto et al., 2023; Sakr & Abdullah, 2024).

Augmented Reality (AR) offers one possible path to address these limitations by connecting the physical learning context with a digital three-dimensional representation. Virtual objects can be positioned within the learner's real environment allowing students to examine the technical components from a variety of perspectives while receiving information relevant to the material being studied. Systematic reviews have reported the beneficial effects of AR on learning and vocational outcomes. The learning experience, although its impact can vary according to the instructional design, the learning setting, and the way the technology is integrated into teaching activities (Ibáñez & Delgado-Kloos, 2018; Chiang et al., 2022; Garzón et al., 2020). In mechanical engineering education, AR has also been used to facilitate the visualization of technical systems and machine-related objects (Dani et al., 2022; Sabila et al., 2025).

AR is particularly relevant for the teaching of milling machine components because some parts have complex shapes and spatial relationships that make them difficult to adequately communicate through conventional two-dimensional illustrations. Three-dimensional AR representations can provide learners with a more explicit view of each component and its relationship to the others, which can support technical understanding and engagement. Previous studies have reported that AR-based visualizations can help develop technical knowledge, understanding, and engagement of learners in vocational and engineering contexts (Bacca et al., 2018; Chang et al., 2022). Similar applications have been reported in manufacturing training and workshops, where digital information is displayed alongside physical equipment. to support learners in understanding machine procedures and operations (Gualtieri et al., 2024; Damgrave et al., 2024).

The potential use of augmented reality (AR) technology in vocational learning has been demonstrated through a number of studies conducted in Indonesia. Dani et al. (2022), for example, utilize AR to develop learning applications about automotive differential systems. In the field of mechanical engineering, Satrianto et al. (2024) developed AR-based learning media to deliver basic mechanical engineering content. Another study by Putra et al. (2025) reported an increase in student learning outcomes after the implementation of AR in lathe teaching, while Salim et al. (2025) developed AR-based learning media for TU-2A CNC content. Although these studies have shown the application of AR in various vocational fields and learning topics, research that specifically examines the influence of AR-based learning media on student learning outcomes related to the function of milling machine components at the vocational high school level is still relatively limited. Further study of the use of AR in the teaching of milling machines is needed to determine its potential in helping students understand the function of each machine component in a more concrete way.

Thus, this study focuses on the use of augmented reality-based learning media to help improve student learning outcomes in understanding the function of milling machine components in mechanical engineering specialization programs . The findings are intentional to provide empirical information that may help vocational teachers and schools when considering digital media for engineering subjects and may also provide a basis for further research on the application of AR in mechanical engineering and vocational engineering education.

METHODS

The quantitative approach was chosen because this research produced numerical data that was then analyzed. statistically. The research employed A quasi-experimental design Because it was experimental and group control consisted of existing classes more precisely than classes formed through random assignments. Specifically, the study used A research design using two groups, namely pretest and posttest. This research was carried out at SMK Negeri 1 Semarang, Jl. Dr. Cipto, Semarang City, Central Java in the 2025/2026 school

year.

The alignment of the characteristics of the subject and object with the focus of the research serves as the basis for defining the research population. (Sugiyono, 2017: 117). This research involved all grade XI students majoring in mechanical engineering at SMA Negeri 1 Semarang as a research population, which consisted of three classes: XI TM 1, XI TM 2, and XI TM 3.

Sugiyono (2017: 118) describes a sample as a subset of a population that represents its relevant characteristics. Therefore, sampling is carried out so that the selected participants can adequately represent the population studied. The sampling technique used in this study is probability sampling. The sample members were randomly selected using a stratified proportional random sampling method through a lottery mechanism.

This approach provides an opportunity for population members to be selected without deliberately excluding certain elements (Sugiyono, 2017). In this study, two existing classes were selected as research subjects, namely class XI TM 1 as the experimental group and class XI TM 3 as the control group. The independent variable is the implementation of Augmented Reality (AR)-based learning media, while student learning outcomes function as dependent variables. To obtain the required data, the researchers used several data collection techniques, including tests, observations, and documentation.

Several procedures are applied to establish the validity and reliability of the research data. For the content of the learning media, the validity of the content is evaluated using the Lawshe procedure through the calculation of the Content Validity Ratio. (CVR), followed by an analysis with the Content Validity Index (CVI). The method was selected based on Hendryadi (2017: 174), who described it as an established and commonly used approach to assess the validity of the content through experts' decisions. The reliability of the content media is examined using the percentage of agreement. McHugh (2012), as cited in Khumaedi et al. (2021: 617), suggests that CVR and CVI results supported by a percentage value of at least 80% agreement can be considered reliable.

The Aiken formula is employed to evaluate the validity of the instrument test using a list of data questions assessed by experts. Four experts participate in the assessment, using seven ranking categories scored from 0 to 6. According to Aiken (1985:134), when seven categories are used and three experts are involved, an index of at least 0.75 indicates validity. The reliability of the instrument test is assessed through the In the Correlation Coefficient (ICC) class, which measures the level of agreement between experts when evaluating aspects of the instrument (Ismunarti et al., 2020). The results of the expert assessment were processed using SPSS. The research data was analyzed based on two types of scores: pretest and posttest. Initially, the pretest scores were compared using a two-way independent sample t-test. This analysis was performed to determine if there was a difference in the initial ability of the two groups before the administration of the treatment.

The analysis of post-test scores began with the presentation of descriptive statistics to provide an overview of the variables studied by Febriani (2022). The analysis was carried out with SPSS. Then normality and homogeneity tests were performed. After the data met the assumptions of normality and homogeneity, the analysis continued using the right-sided T test to examine the difference in average learning outcomes between the experimental group and the control group, based on the hypothesis that the average of the experimental group would be higher. Furthermore, the N-Gain analysis was used to measure the rate of improvement in student learning outcomes based on pretest and posttest scores.

RESULTS AND RESULTS OF THE DISCUSSION

Validity And Reliability Test Results From The Instrument Test

Table 1. Results of the Validation Instrument Test Using Aiken's V

NO	Indicator	Aiken's V	Category
1	Item 1	0,83	Valid
2	Item 2	0,83	Valid

3	Item 3	1	Saw
4	Item 4	0,83	Saw
5	Item 5	1	Saw
6	Item 6	0,83	Saw
7	Item 7	1	Saw
8	Item 8	1	Saw
9	Item 9	0,83	Saw
10	Item 10	1	Saw
11	Item 11	1	Saw
12	Item 12	1	Saw
13	Item 13	1	Saw

Source :D processed using IBM SPSS Statistics 25 (2026)

The Aiken's V coefficient shown in Table 1 ranges from 0.83 to 1.00. Thus, each indicator of satisfaction it meets the specified validity requirements and is judged accordingly for inclusion in the study.

Table 2. Instrument Reliability Test

Types of ICC	ICC Value	Category
Single measurement	0,854	Good
Average size	0,972	Very good

Source : IBM SPSS Statistics 25 Processing Results (2026)

The ICC results in Table 2 show the strong reliability of the test instruments. The single measurement coefficient is 0.854, while the average measurement coefficient reaches 0.972. These values indicate a high level of consistency among the validators and support the suitability of the instrument for use in the study.

Table 3. Media Validation Results Using CVI

Statement	Member Ratings			Total Fitness	I- CVI
1	5	5	5	3	1
2	5	5	5	3	1
3	5	5	4	2	0,67
4	5	5	5	3	1
5	5	5	5	3	1
6	4	4	5	1	0,33
7	5	5	5	3	1
8	5	5	5	3	1
9	5	5	4	2	0,67
10	5	5	5	3	1
11	4	5	5	2	0,67
12	5	5	5	3	1

13	5	5	5	3	1
Total	63	64	63	Rasio I-CVI	0,872

Source :D processed using IBM SPSS Statistics 25 (2026)

The CVI analysis showed that most individual items achieved an I-CVI value of 1.00. The overall I-CVI ratio was 0.872, which indicates that the media content instrument has a good level of content validity. On this basis, the instrument is considered valid and appropriate for the study.

The Result of the Reliability Test of the Media Content Instrument Using the approval percentage

$$\text{Percent Deal} = \frac{\text{Total Agreed Values}}{\text{Total Agree + Disagree}} \times 100\%$$

$$= \frac{34}{34+5} \times 100\% = 87,18\%$$

The calculation of the percentage of agreement resulted in a value of 87,18%. The developed instrument achieved a high level of agreement among the validators, which showed a strong consistency in their assessments. The instrument could therefore be used in it learning while taking into account the inputs and recommendations provided by the experts.

Tabel 4. Independen Sample t-test

Variabel	Groups	Mean	T	Sig. (2- Tailed)
Pretest	Control	58,66	- 1.461	0,149
Pretest	Eksperimen	59,49		

Source :D processed using IBM SPSS Statistics 25 (2026)

An independent sample t-test for the pre-test score yielded a significance value of 0.149 ($p > 0.05$). This means that it was experimental and the control group had performed instead of showing a statistically significant difference within their initial score. Therefore, their initial learning ability levels could be considered relatively comparable before the intervention.

The results of the Test Prerequisites

Table 5. Descriptive Statistical Results

Classes	N	Min	Max	Average	Standard Deviation
Experiment	35	80	89	84,63	2.315

Sources :D ata are processed using IBM. SPSS Statistics 25 (2026)

The descriptive results in Table 5 show that the experimental group obtained an average posttest score of 84.63 with an A standard deviation of 2.31. The control group had an A mean of 70.49 and an A standard deviation of 2.40. The difference between these mean scores showed higher post-test learning outcomes for students in the experimental group after the treatment.

Table 6. Shapiro-Wilk Normality Test Posttest Score

Groups	Say.	Distribution
Control	0,391	Normal
Experiment	0,482	Normal

Source :D processed using IBM SPSS Statistics 25 (2026)

Shapiro-Wilk's analysis of posttest scores yielded significance values above 0.05 for both groups. The control group obtained 0.391 and the experimental group 0.482. Thus, the score distribution in both groups met the normality assumptions required for subsequent parametric analysis.

Table 7. Homogeneity Test

	Living State	df1	df2	Sig	Category
Based on Mean	0,168	1	68	0,683	Homogeneous

Source :D processed using IBM SPSS Statistics 25 (2026)

For the posttest data, Levene's test generated a statistical A value of 0.168 with an A mean value of 0.683. Since the significance value is above 0.05, the variance of the experimental group and the control group can be considered homogeneous.

Hypotheses

Table 8. Right-side t-test

	Sig. (2-tailed)	Mean Difference	Std. Error Difference	t	df
Equal Variances Assumed	0,001	-14,143	0,564	-25,063	68

Data sources are processed using IBM SPSS Statistics 25 (2026)

The right-tail t-test yielded a calculated t-value of 25.063 with 68 degrees of freedom. At a significance level of 0.05 level, the critical value was 1.668. Since 25.063 exceeded 1.668, H_0 was rejected and H_a was accepted. The results showed that the AR-based learning media was producing higher learning outcomes than the conventional learning media used for comparison.

Table 9. N-Gain Test

Data	Pretest	Posttest	Maximum Value	Score N- Gain
Eksperimen	59,49	84,63	100	0,622
Controls	58,66	70,49	100	(Medium) 0.286 (Low)_

Data sources are processed using IBM. SPSS Statistics 25 (2026)

Table 9 shows an N-Gain value of 0.622 for the experimental group and 0.286 for the control group. The experimental group had a higher N-Gain value. The waterfall within it was moderate in the moderate category, whereas the latter was secretive as low. Thus, it increased in the learning The results observed in the experimental group were greater than those observed in the control group.

DISCUSSION

The initial equivalence of ability between the two groups prior to the administration of the treatment was demonstrated by the pre-test results. The significance level of 0.149 was higher than 0.05, so the difference between their initial average scores was not statistically significant. This provided a reasonable basis for interpreting the subsequent post-test comparison as neither group showed a statistically significant difference. Important early gain. After it was learning the intervention, the experimental group obtained an A meaning posttest score of 84.63, compared to 70.49 for the control group. The one-sided t-test also showed a statistically significant difference according to the expected direction. These findings are consistent with previous research that suggests that AR can support learning. Advantage When it is incorporated into a precisely designed instructional process. Garzón and Acevedo (2019), for example, reported a moderate overall effect of AR on improved student learning. Chang et al. (2022) also identified the positive effects of AR on knowledge, skills, and performance in a meta-analysis of quasi-experimental studies.

The results of this study are also relevant to vocational engineering and mechanical engineering education. Supriyanto et al. (2023) report that AR can provide a more concrete learning experience and support understanding in a vocational environment. Dani et al. (2022) and Satrianto et al. (2024) also demonstrate the feasibility of AR-based media for mechanical engineering and engineering. instructions. In the learning rewards, AR is directed specifically at the functions of the machine grinding parts. Three-dimensional representation

allows students to examine machine components more directly than relying solely on static conventional representations. Evidence from industrial and workshop training further supports this interpretation. Gualtieri et al. (2024) found that AR-assisted training can support both short-term and long-term procedural retention. knowledge during the complex of activity regulation machines. Damgrave et al. (2024) also reported that AR It can support learners' understanding of machine operation and safety procedures in an engineering workshop environment. These findings provide a possible explanation for the usefulness of three-dimensional contextual visualization in milling teaching, where students must identify different forms of components while simultaneously understanding how they operate in relation to each other.

The N-Gain results provided additional descriptive information about the improvement in both groups. The experimental group recorded an N-Gain of 0.622, categorized as moderate, while the control group obtained 0.286, categorized as low. Similar patterns have been reported in vocational studies in Indonesia, including Putra et al. (2025) on AR-supported lathe instruction and Salim et al. (2025) on CNC learning. Nonetheless, the N-Gain being in the experimental group suggests that AR should not be treated as a stand-alone A solution to improve learning outcomes. Its contribution may depend on learning conditions such as activity design, teacher assistance, duration of learning tasks, and integration of AR with appropriate pedagogical approaches (Garzón et al., 2020; Chiang et al., 2022).

Overall, this study extends that there is evidence by examining a specific grinding machine topic within a vocational high school education. He contributes lies in the comparison of AR-based and conventional instructions to the study of the function of grinding machine parts through a quasi-experimental design using pre-test and posttest measurements. Future studies could examine longer intervention periods, recruit a larger and more diverse sample, discuss additional machining topics, and evaluate whether learning improvements are sustained over longer follow-up periods.

CONCLUSION

The application of augmented reality-based learning media has been proven to have a positive impact on student learning outcomes related to the function of grinding machine components. The overall feasibility score of the media, based on expert assessment, reached 87.97%. Regarding the research instrument, the validation results showed that the Aiken's V coefficient ranged from 0.83 to 1.00, while the analysis of the Intraclass Correlation Coefficient (ICC) showed a high level of reliability.

Before the learning intervention was implemented, the initial conditions of the two groups were relatively comparable, as shown by the pretest analysis, which resulted in a significance value of $0.149 > 0.05$. After the learning and treatment processes were completed, the experimental group using AR-based learning media achieved an average posttest score of 84.63. In comparison, the control group, which received instruction without AR-based media, obtained an average score of 70.49. The results of the prerequisite analysis test showed that the research data met the normal distribution criteria and had homogeneous variance. Subsequent testing using the right-tail T-test resulted in a calculated t-value of 25.063, compared to a critical value of 1.668 at a significance level of $\alpha = 0.05$. The fact that the calculated t-value exceeded the critical value showed a statistically significant difference in learning achievement between the experimental group and the control group.

Further improvement in learning outcomes was shown by the N-Gain analysis. The experimental group obtained an N-Gain score of 0.622, which was categorized as moderate, while the control group obtained a score of 0.286, which fell into the low category. Overall, these findings suggest that AR-based learning media can be considered an alternative approach to support the learning process regarding the function of milling machine components in vocational education.

REFERENCES

- Aiken, L. R. (1985). Three Coefficients to Analyze the Reliability and Validity of Ratings. *Psychological Education and Measurement*, 45(1), 131–142. <https://doi.org/10.1177/0013164485451012>
- Chiang, F., Shang, X., & Qiao, L. (2022). Computers in Human Behavior Reinforced realities in vocational training: A systematic review of research and applications. *Computers in Human Behavior*, 129 (April 2021), 107125. <https://doi.org/10.1016/j.chb.2021.107125>

- Cholik, M. (2023). Evaluation of the Relevance of Advanced Machining Materials in Vocational Schools to the Manufacturing Industry in Surabaya. *Journal of Mechanical Engineering Education Undiksha*, 11 (1). <https://doi.org/https://doi.org/10.23887/jptm.v11i1.58000>
- Damgrave, R.G., Knollema, S.L., & Lutters, E. (2024). Engineering workshop education and supervision: AR for machine operation guidance and safety instruction. *Procedia CIRP*, 128, 430–435. <https://doi.org/10.1016/j.procir.2024.03.023>
- Dani, D. F., Ramdani, S. D., & Supriyatna, D. (2022). Developing an enlarged reality on differential systems, competency systems, and power transfers in vocational education. *Journal of Vocational Education*, 12(2), 152–167. <https://doi.org/10.21831/jpv.v12i2.48804>
- Garzón, J., & Acevedo, J. (2019). Meta-analysis of the impact of augmented reality on student learning advantage. *Research Education Review*, 27, 244–260. <https://doi.org/10.1016/j.edurev.2019.04.001>
- Garzón, J., Kinshuk, Baldiris, S., Gutiérrez, J., & Pavón, J. (2020). How does pedagogical approaches affect the impact of augmented reality on education? A meta-analysis and synthesis of research. *Educational Research Review*, 31, 100334. <https://doi.org/10.1016/j.edurev.2020.100334>
- Gualtieri, L., Öhler, M., Rebellion, A., & Dallasega, P. (2024). A visual management and augmented reality-based training module for improving short-term and long-term procedural knowledge retention in complex machine settings. *Computer & Industrial Engineering*, 196, 110478. <https://doi.org/10.1016/j.cie.2024.110478>
- Ibáñez, M.-B., & Delgado-Kloos, C. (2018). Augmented reality for STEM learning: A systematic review. *Computer & Education*, 123, 109–123. <https://doi.org/10.1016/j.compedu.2018.05.002>
- Khumaedi, M. (2012). Reliability of Educational Research Instruments. *Journal of Mechanical Engineering Education*, 12(1), 25–30. <https://doi.org/10.15294/jptm.v12i1.5273>
- Khumaedi, M., Widjanarko, D., Setiadi, R., & Setiawan, A. (2021). *EVALUATING THE IMPACT OF AUDIO-VISUAL MEDIA ON LEARNING OUTCOMES OF DRAWING ORTHOGRAPHIC PROJECTIONS*. 9 (3), 613–624. <https://doi.org/10.18488/journal.61.2021.93.613.624>
- Putra, R., Wulansari, R.E., Waskito, & Primandari, SRP (2025). Implementation of augmented reality lesson media to improve learning outcomes in machine education subjects but grade XI ordering techniques of SMK Dhuafa Padang. *Journal of Education Tambusai*, 9(1), 6907–6912. <https://doi.org/10.31004/jptam.v9i1.25583>
- Sabila, A., Refdinal, Waskito, Effendi, H., & Alawyah, K. (2025). Augmented reality in educational vocational engineering engineering: A systematic literature review. *Indonesian Journal of Education Research*, 11(3), 413–424. <https://doi.org/10.29210/020256446>
- Sakr, A., & Abdullah, T. (2024). The impact of virtual reality, augmented reality, and learning analytics on learners and educators: A systematic review. *Education and Information Technology*, 29, 19913–19962. <https://doi.org/10.1007/s10639-024-12602-5>
- Salim, R.A., Syahril, & Erizon, N. (2025). Improving vocational education through augmented reality: Android-based learning media for CNC TU-2A teaching in engineering vocational high schools. *Journal of Engineering Researchers and Lecturers*, 4(2), 103–114. <https://doi.org/10.58712/jerel.v4i2.188>
- Satrianto, H.I., Syahri, B., Abadi, Z., Wulansari, R.E., & Media, A. (2024). Development of augmented reality learning media in the basics of mechanical engineering education. *Journal of Vocational Mechanics*, 6(3), 271–279. <https://doi.org/10.24036/vomek.v6i3.723>
- Sugiyono. (2017). *Educational Research Methods of Quantitative, Qualitative Approach and Research and Development*. ALPHABET.
- Supriyanto, S., Joshua, Q., Abdullah, A. G., Tettehio, E. HAI., & Ramdani, S. D. (2023). Application of augmented reality (AR) in vocational education: A systematic literature review. *Journal of Vocational Education*, 13(2), 205–213. <https://doi.org/10.21831/jpv.v13i2.54280>