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The Effectiveness of Augmented Reality–Based Learning Media on Grade X Students' Learning Outcomes in Computer Hardware Materials

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Abstract

This study aims to determine the effectiveness of augmented reality-based learning media on student learning outcomes regarding computer hardware within the Informatics subject. Currently, instruction on computer hardware relies heavily on conventional media, such as textbooks and oral explanations, which have limited ability to support students' visual understanding of abstract components. Consequently, students tend to be passive, struggle to maintain focus, and often achieve learning outcomes below the minimum mastery criteria. This study employs the ADDIE development model and a quasi-experimental design, specifically a posttest-only control group design. The results indicate that augmented reality-based learning media significantly improve student learning outcomes compared to conventional learning media. The effectiveness of the augmented reality-based learning media is demonstrated by an n-gain score of 0.76 in the experimental group, which falls into the "effective" category. Thus, this augmented reality learning medium is effective in the learning process. Furthermore, statistical analysis yielded a t-calculated value of 6.971, which is substantially higher than the t-table value of 1.995. Since the t-calculated value exceeds the t-table value and the significance level is below 0.05, the null hypothesis (H_0) is rejected, and the alternative hypothesis (H_1) is accepted. Therefore, it can be concluded that there is a statistically significant difference in the mean posttest scores between the experimental group and the control group.
Keywords: Effectiveness, Augmented Reality, Computer Hardware, Statistical Analysis

Introduction

Education is a systematically designed and consciously implemented process aimed at optimally developing individual potential. This potential encompasses key aspects, namely affective, psychomotor, and cognitive. (Law Number 20 of 2003 concerning the Definition of Education, 2004) This potential encompasses key aspects, namely affective, psychomotor, and cognitive.

The Indonesian dictionary defines education as a consciously occurring process aimed at shaping and changing individual attitudes and behaviors through learning and training activities facilitated by an educator, namely a teacher. In carrying out their duties, teachers are responsible for developing learning tools such as syllabi and lesson plans, which include essential components such as competency standards (SK), basic competencies (KD), competency achievement indicators, learning objectives, materials, time allocation, learning methods, learning activity steps, assessment of learning outcomes, and relevant learning resources (Minister of National Education Regulation No. 41 of 2007 concerning Process Standards, 2007). During the learning process,

teachers play an active role in developing active learning, involving students in discussions, projects, experiments, and other activities. Furthermore, teachers are required to utilize available media to ensure the material is easily understood.

In the learning process, teachers serve not only as sources of information but also as facilitators. As facilitators, teachers should provide learning resources with strong learning media, whether in print or in the form of applications/apps, that are attractively packaged and not monotonous. In this modern era, developing and utilizing learning media in the form of applications is crucial to creating an engaging, interactive, and enjoyable learning experience for students. Mayer (2002) explains that material presented in a combination of text and images has been proven to improve the quality of the learning process compared to presentations using only text. Mayer also suggests that delivering material through text combined with animation can provide more effective support and facilitate student understanding.

In the 21st-century era of Society 5.0, science and technology are developing rapidly, requiring people to prepare for global changes, particularly in education. These changes are evident in the learning process, where lectures are No. longer sufficient; teachers now need to update their teaching methods by using technology to improve human resource quality (Rahmadila et al., 2023). The development of knowledge in line with technology has significantly impacted education, particularly the learning process. Currently, teachers can use technology to deliver material and support more effective learning activities.

Information and Communication Technology (ICT) is a key component of Informatics. ICT provides a crucial foundation for students to become increasingly digitally connected (Harahap, 2023). ICT elements provide students with the skills to face today's technological challenges. In addition to introducing various software tools, ICT learning also emphasizes developing in-depth digital competencies, including a strong understanding of computer systems (hardware and software) (Wirasasmita et al., 2025). Through learning ICT elements, students are expected to improve their conceptual understanding and technical skills effectively (Gusti A et al., 2024).

Although ICT plays a crucial role and prepares students for the digital era, its implementation still faces significant challenges. The 2022 PISA report shows that Indonesian students' digital literacy and technology-based problem-solving skills remain suboptimal (OECD, 2023). Furthermore, a report by the Center for Assessment and Learning (2022) found that student achievement in digital literacy and technology utilization remains low. The primary factor influencing students' low technological mastery and achievement in technology utilization is a lack of student engagement and motivation in the learning process (Melita, 2024). Factors influencing low student participation include individual factors, the environment, and educators' role in creating a conducive learning atmosphere through an interactive approach relevant to the subject.

Several previous studies have reported that Augmented Reality (AR) can enhance student motivation and conceptual understanding. However, most existing studies focus primarily on media development or feasibility testing, with limited empirical evidence examining the effectiveness of AR learning media through experimental comparison designs, particularly at the senior high school level and in computer hardware materials. Therefore, this study's novelty lies in its empirical examination of the effectiveness of AR-based learning media developed through the ADDIE model and tested using a quasi-experimental method supported by statistical analysis.

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Method

This research and development study aimed to produce a product as an application that can be run on gadgets. This research adopts the ADDIE development model, which has five development stages. (Branch, 2009) The five stages are analysis, design, development, implementation, and evaluation. After developing the media, the researcher used a quasi-experimental method with a Posttest-Only Control Group Design to test the effectiveness of the learning media. The researcher used a quasi-experimental method with a Posttest-Only Control Group Design to test the effectiveness of the learning media.

	pretes	treatment	posttes
Experimental Class	T_1	X_1	T_2
Control Class	T_3	X_2	T_4

Information:

T_1= Pretest of experimental class (treatment class)

T_2 = Posttest of experimental class (treatment class)

T_3 = Pretest of control class (class not given treatment)

T_4 = Posttest of control class (class not given treatment)

X_2= *The treatment given is conventional*

X_1= *Augmented Reality-based learning media treatment*

This method was chosen because field conditions did not allow randomization of research subjects, as the classes had already been formed. This design was used to determine differences in learning outcomes between the group receiving treatment and those who did not, with measurements taken only after the learning process. The research subjects were tenth-grade high school students. The research sample consisted of two classes selected through purposive sampling. Class X-E was designated as the experimental group that received learning using Augmented Reality media. In contrast, class X-B served as the control group and followed conventional learning methods based on the teacher's habits.

This study collected quantitative data. The data sources were primary data from students' post-test scores. Data were collected using three techniques: tests, questionnaires, and observation. Post-tests were used to measure students' learning outcomes after participating in the learning process. Questionnaires were used to collect data for assessing the developed instruments. At the same time, observations were conducted to monitor the learning process in the classroom in both the experimental and control groups. The questionnaire instruments were designed as a rating scale from 1 to 5. This scale was used to measure the assessments of media experts, subject matter experts, and student responses to the Augmented Reality media used. To ensure the instruments are valid, a validity test was conducted to confirm they could measure the intended aspects. The Augmented Reality media validation grid filled out by media experts, subject matter experts, and students is presented in Tables 1, 2, and 3.

Post-test data were analyzed descriptively to describe the mean, standard deviation, and score distribution. Subsequently, inferential analysis was conducted using an independent-samples

t-test to examine differences in learning outcomes between the two groups. Before the t-test was conducted, the data were tested for normality using the Smirnov test and for homogeneity of variance using the Levene test at a significance level of 5%. The research instrument validation process was carried out using the method described (Sugiyono, 2017).To ensure content validity, the researcher involved experts who were competent and knowledgeable about the studied variables. Qualitative data from the validation were analyzed using descriptive techniques. After obtaining a validity score for the Augmented Reality-Based Learning Media developed to improve student learning outcomes in computer hardware material, the next step was to test its effectiveness.

Table 1. Questionnaire Instrument Grid for Expert Material Suitability

Aspect	Indicator	Question Number	Number Item
Relevance	Alignment of material with learning outcomes	1	1
	Alignment of material with learning objectives	2	1
	Alignment of questions with learning outcomes	3	1
Materials	Consistency of material	5	1
	Material coverage	6	1
	Clarity of material	7	2
	Language	9.10	2
	Content alignment with images	11	1

(Noviarni., 2014)Modified to assess the suitability of the material by subject matter experts.

Tabel 2. Questionnaire Instrument for Media Suitability Assessment by Experts

Aspect	Indicator	Question Number	Number Item
Use	Ease of use of learning media	1	1
	Availability of navigation	2	1
	Availability of instructions for use	3	1
Design	Interaction between teaching materials and readers	4	1
	Completeness of teaching materials	5	1
	Clarity of material	6	1
	Sequence of material	7	1
	Font selection	8	1
Visual	Color selection	9	1
	Image relevance to content	10	1

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Image layout	1	1
Animation clarity	1	1
Image clarity	13	1

(Wahono, 2006) With modifications to assess media suitability by media experts.

Tabel 3. Learning Outcome Test

Learning Outcomes	Indicators	Cognitive Level	Questions
Students are expected to have a comprehensive understanding of the functions of operating systems and the internal processes involved in managing interactions between hardware, software, and users.	Students can identify and recognize computer hardware components (names, images, terms, and basic functions)	C1 (Remembering)	1,2,4,6,8, 11,13,16, 18,20
	Students can classify and understand the functions of input, processing, output, and storage hardware.	C2 (Understanding)	3,5,7,9,10 ,14,15,17, 19

This effectiveness test used a research design to demonstrate the success of media use, with analysis conducted using a correlated t-test in SPSS version 29.

Results

The effectiveness test used a quasi-experimental design with an experimental class. The research subjects were students from classes XB and XE at SMAN 1 Teminabuan. The variable observed was learning outcomes. Figure 1 compares scores between classes that used augmented reality-based media and those that did not.

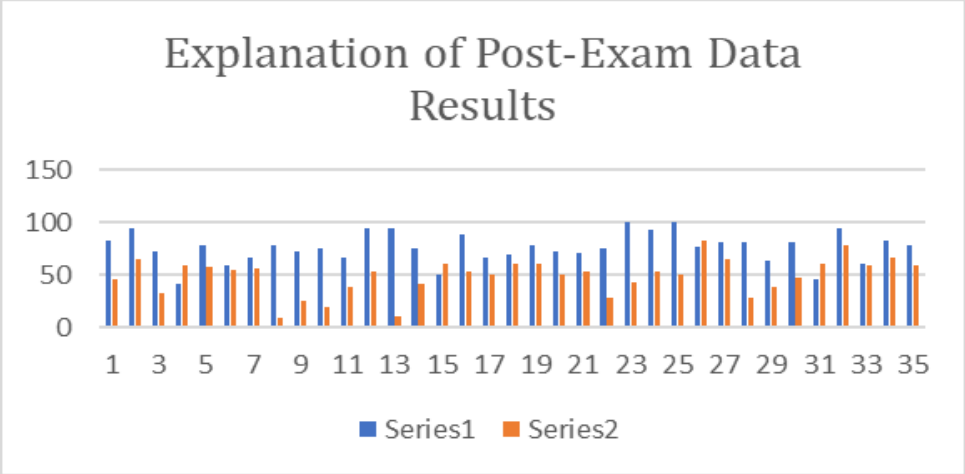


Figure 1. Graph of Post-test Results Comparison XB &Post-test XE

The bar chart, titled "Explanation of Post-Exam Data Results," presents a comparison of exam scores between group XB (blue bars) and group XE (orange bars) across 35 data samples. Overall, group XB scores dominate and are significantly higher than group XE scores in most samples. Group XB's performance is relatively stable, with scores ranging from 50 to 100, including perfect scores of 100.

Preliminary Test Results

Before conducting a correlation analysis on students' post-test results, this study conducted a series of prerequisite tests. These steps included testing the normality of the data distribution and the homogeneity of variance. The entire prerequisite testing process was conducted using SPSS version 29 for Windows, and the analysis results are presented in Table 4.

Table 4. Regular Distribution Test of Data

Results	Post-test (Experimental Class)	Post-test (Control Class)
N	35	35
Average	80.5	64.29
Standard deviation	10.831	8.587
Sig.	0.176	0.063

Source: data from the researcher (2025)

Based on the normality analysis conducted on the post-test scores, a significance value of 0.176 was obtained for the experimental class. Meanwhile, the normality test for the control class showed a significance value of 0.063. Since both significance values are greater than 0.05 (5%), we conclude that the post-test data from both classes follow a normal distribution. For more complete information on the normality test results, see SPSS version 29. After the data are declared normally distributed, the next step is to conduct a homogeneity test. This test determines whether the variances of the two groups of research subjects differ. Homogeneity of variance is met if the test significance value is greater than 0.05.

Table 5. Homogeneity of Variance Test

Learning Outcomes	Based on Mead	Levene's Statistics	df	df	Sig
		1.642	1	68	0.204

Source: data from the researcher (2025)

The test for homogeneity of variance yielded a significance value of 0.204, which is above the $\alpha = 0.05$ threshold. Consequently, the data meet the requirements to proceed to the next stage of statistical analysis: calculating the Normalised Gain (N-gain) to assess the effectiveness of the learning method used.

N-Gain Test Results

The N-Gain test was used to assess improvements in students' learning outcomes after participating in the learning process using AR-based media. Based on the gain score interpretation categories, scores above 76% were classified as effective. The N-Gain analysis in this study was conducted using SPSS version 29. The test results are presented in Table 6.

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Table 6. N-Gain Test

Class	N	Minimum	Maximum	Mean	Standard Deviation
Experimental	35	42	100	76.03	14,170
Control	35	10	83	49.17	16,888
Valid N (listwise)	35				

Source: data from the researcher (2025)

The N-gain test was conducted to measure improvement in student learning outcomes after using AR media. The results showed that the experimental class's average score was 76.03%, which falls into the high (effective) category. Meanwhile, the control class only obtained a score of 49.17%, which falls into the low category.

T-Test Results

To determine whether the difference in N-gain scores between the experimental and control groups is significant—rather than merely a result of chance—the analysis proceeded with an independent-samples t-test, based on the assumption of homogeneous variances (equal variances assumed).

Prior to determining the t-test results, Levene's test for equality of variances (Table 2) was conducted to assess this assumption. The test yielded an F-value of 1.642 and a significance value (Sig.) of 0.204. Since the significance value is greater than α = 0.05 (0.204 > 0.05), it can be concluded that the variances of the two data groups are homogeneous.

Table 7. Independent Samples Test

Independent Samples Test					
		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	Df
Results	Equal variances assumed	1,642	0,204	6,971	68
	Equal variances not assumed			6,971	64,638

Source: data from the researcher (2025)

A summary of the Independent Samples t-Test analysis results for the post-test variable is presented in Table 3 below:

Independent Sample t-Test Results

Table 8. Independent Samples Test

Variables	Identifying Data Variance	*t-test for Equality of Means*			Sig.
Post-test	*equal variances assumed.*	$t_{calculated}$	t_{table}	Df	0.01
		6,971	1,995	68	

Source: data from the researcher (2025)

The table presents the results of an independent-samples t-test on the post-test variable, assuming homogeneous variances (equal variances assumed) and 68 degrees of freedom (df). Based on the statistical calculations, the obtained $T_{calculated}$is 6,971, which is significantly greater than the critical T_{table} of 1,995 (6,971 > 1,995). Furthermore, the significance value (Sig.) is 0,01, which is below the α = 0,05 threshold (0,01 < 0,05). Since $T_{calculated} > T_{table}$ the significance value is less than 0,05, the Null Hypothesis (H_0) is rejected, and the Alternative Hypothesis (H_1) is accepted. Consequently, it can be concluded that there is a statistically significant difference in the mean post-test scores between the two sample groups. This finding indicates a significant difference between the learning outcomes of students who used AR media and those who did not. This finding shows that AR-based learning media improves student learning achievement.

Discussion

This study aimed to test the effectiveness of Augmented Reality (AR)-based learning media on tenth-grade students' learning outcomes in computer hardware. Based on the analysis results, the AR media developed through the ADDIE model met high content and media feasibility criteria, with content feasibility scores of 84% from the content expert and 86% from the media expert. These results indicate that AR has content and presentation quality suitable for use as a learning medium. Additionally, practicality tests involving teachers and students in small-scale and large-scale trials showed a convenient category, with scores of 97% (students) and 87% (teachers) in the small-scale trial, and 92% in the large-scale trial.

The purpose of implementing a pre-test and post-test was to evaluate the effectiveness of Augmented Reality (AR)-based learning media in improving student learning outcomes. The pre-test was administered before students received the learning media treatment. This study analyzed the media's effectiveness and involved two groups: an experimental group and a control group. The experimental group received AR-based learning media, while the control group received conventional instruction without AR media.

Learning outcomes were measured through a single pre-test and post-test, each administered using the same questions. After the learning process (treatment) was completed, a post-test was administered to assess the improvement in student learning outcomes after receiving the specific treatment. Furthermore, post-test evaluation data were also used to classify the effectiveness of the learning media. T-tests and N-Gain tests were conducted to evaluate differences in the effectiveness of using Augmented Reality-based learning media on student learning outcomes and to determine whether these differences were statistically significant. The t-test was used to identify significant differences in learning outcomes between the group using Augmented Reality media and the group learning without such media.

The t-test results showed a significant difference in learning outcomes between students who used Augmented Reality-based learning media and those who did not. The findings indicated that students who used Augmented Reality consistently demonstrated higher learning outcomes than the group that did not use similar media.

After the t-test revealed differences in student learning outcomes, an N-Gain test was conducted to determine the effectiveness of Augmented Reality-based learning media. The results revealed that the average N-gain score in the experimental class reached 76.03%, which is categorized as effective (greater than 76%). In contrast, the average N-gain score for the control class was only 49.17%, which is categorized as insufficient. This finding indicates that the

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experimental group improved more than the control group, supporting the effectiveness of the learning media (Arikunto, 2017). This study's results align with Arsyad (2017): interactive learning media can increase motivation, help students understand the material, and facilitate information delivery by educators. AR features such as 3D animations, interactive visualizations, and digital exercises have been shown to help students visualize computer hardware components that are difficult to observe directly. Additionally, this medium enables self-directed learning as it can be accessed anytime and anywhere without spatial or temporal constraints.

The findings strengthen constructivist learning theory, which emphasizes that students actively construct knowledge through interaction with learning media. Practically, AR-based learning media can be used by teachers as an innovative instructional alternative to improve engagement and learning outcomes. This study has limitations, including a small sample size and a focus only on cognitive learning outcomes. Future research should involve broader samples and explore long-term learning retention.

Conclusion

Augmented Reality (AR)-based learning media for computer hardware material is highly suitable, based on assessments by subject matter experts and media experts, with a suitability score in the highly suitable category. Additionally, this medium has proven highly practical in the learning process, as shown by positive feedback from teachers and students in both small-scale and large-scale trials. AR-based educational media also improves students' learning outcomes in grade X, as shown by significant differences in post-test scores between the experimental class using AR media and the control class that did not. The N-Gain scores for the experimental class fall into the effective category, while the control class remains in the less effective category. Augmented Reality-based learning media effectively improves student learning outcomes in computer hardware materials. However, this study was limited to a The development of Augmented Reality learning media in this study is still limited to Android-based devices, so it does not yet support use on other operating systems, such as iOS. The computer hardware material in the learning media is also limited to a few components, so the content is not fully comprehensive.

Overall, the learning media was deemed highly suitable for use in teaching and learning activities. Subject matter experts' assessment, which included learning strategies and content suitability, resulted in a total score of 84%, placing it in the highly suitable category. Meanwhile, validation by media experts, which evaluated user design and visual appearance, achieved a score of 86%, also within the highly suitable criteria. Practicality of Learning Media: Test findings indicate that this Augmented Reality learning media is highly practical for learning activities. The initial field trial obtained a practicality score of 97%. The trial by informatics teachers yielded a score of 87%.

Furthermore, the main field trial also showed a high practicality percentage of 97%. These results indicate that the media is highly practical. Effectiveness of Learning Media: The learning media using Augmented Reality technology is effective for learning activities, as shown by the gain score in the experimental class, which reached 0.76 and is considered high. This figure shows that the developed media is effective and positively contributes to improving student learning outcomes.

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