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Integrating AR Technology to Improve Informatics Learning Outcomes

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Abstract - In the era of the Industrial Revolution 4.0, the utilization of digital technology in learning is an important strategy to improve the effectiveness and quality of education. One of the challenges in the learning process is the lack of interactivity of the media used, which impacts the achievement of student learning outcomes. Learning media such as Augmented Reality (AR) offers the potential to create a more engaging, contextual, and immersive learning experience. This study aims to analyze the effect of AR technology integration on improving student learning outcomes in Informatics subjects. This research uses a quantitative approach with a Quasi Experimental design in the form of Pretest-Posttest Control Group Design. The research subjects consisted of 70 students of class X Computer Network and Telecommunication Engineering at State Vocational High School 1 Bukittinggi divided into experimental and control classes. The results showed a difference in the average posttest score of 7.31 points, with a score of 80 in the experimental class and 72.69 in the control class. The Independent Sample T-Test test yielded a significance value of 0.001 (p < 0.05), indicating a significant difference between the two groups. This finding indicates that AR media has a positive impact on improving student learning outcomes. The implications of this research encourage the utilization of interactive technology in the development of learning media in the future.

Keywords— Augmented Reality, Learning Outcomes, Informatics Education.

I. INTRODUCTION

The implementation of 21st century education requires a transformation of learning approaches, especially at the vocational high school level which emphasizes the mastery of practical skills and the development of creativity [1]. Meanwhile, the industrial revolution 4.0 marks a new era in education, where technology is used intensively in the teaching and learning process. Education in this era allows learning to take place continuously without space and time Constraints [2]. Therefore, the utilization of information technology is an important strategy to answer the challenges and needs of today's education .

The use of digital technology in the learning process, or what is known as digitalization of learning, allows students to experience a more realistic learning process and interact with each other without having to meet face to face [3]. Digitalization of learning is a mandatory program, especially to increase the use of technology in learning, especially in Vocational High Schools that are selected as Centers of Excellence. This program aims to create more efficient learning and in accordance with industry needs through the use of various media, devices, and more innovative learning methods [4].

Based on the results of observations during the Educational Field Practice activities in the July-December 2023 period, it was found that the State Vocational High School (SMK) 1 Bukittinggi has implemented the Merdeka Curriculum with a scientific learning approach. The school uses several learning models, such as Problem-Based Learning (PBL), Project-Based Learning (PJBL), and Inquiry-Based Learning, which aim to help students develop critical and creative thinking skills. This is very important in learning Informatics as a basic subject of the expertise program, which contains various competencies to support the ability to think critically and systematically in solving common problems [5].

In the independent curriculum, assessment of learning outcomes by teachers aims to monitor and evaluate the process, learning progress, and improvement of student learning outcomes on an ongoing basis. The results of the assessment can provide a level of educational success in the education unit [6]. Therefore, the Final Semester Examination is one of the important indicators in measuring the quality of education that reflects the understanding and mastery of material by students during one semester. Table 1 presents data on the average Final Semester Examination scores from three different classes, namely class X TKP (Construction and Housing Engineering) and class X TJKT (Computer Network Engineering and Telecommunications), which are all taught by the same Informatics subject teacher. Based on Table 1, it can be seen that the average final semester exam score in Informatics is still relatively low, with an overall average score of 69. In particular, class X TKP 3 shows the lowest

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achievement with an average score of 56. The low learning achievement can be an indication that the learning process has not fully supported the achievement of optimal learning outcomes.

TABLE 1
AVERAGE OF ODD SEMESTER FINAL EXAM IN 2023/2024

No	Class	Number of Students	Average Score
1	X TKP 3	29	56
2	X TJKT 1	35	77
3	X TJKT 2	36	74
Overall Average			69

Teachers' efforts in creating interesting learning are needed so that students are more actively involved [7]. One important factor that can affect the quality of learning is learning media. Learning media is a tool that can be used as an intermediary to facilitate communication between teachers and students, thus creating a more effective, efficient, and easy learning process for students in understanding the material being taught [8]. Students' interaction with the subject matter has changed along with the development of interactive media trends, such as gamification, artificial intelligence, virtual reality, and augmented reality. These trends make the learning process more accessible, interactive, and personable [9].

Learning media such as multimedia presentations, learning videos, interactive games, learning modules, and digital information sources can help students understand and apply concepts [10]. However, the effectiveness of learning media is also largely determined by the teacher's ability to choose the right media, in accordance with the characteristics of students and the teaching material presented [11].

One of the potential media innovations in education is Augmented Reality. Although until now AR has not been widely implemented as a mandatory learning media in educational institutions, its utilization as an interactive learning support media offers a new approach in presenting information. AR technology is not only able to present objects in real but also in visual form which allows the delivery of information to be more interesting and effective, while stimulating students' critical thinking in understanding abstract concepts and complex object model structures, thus making augmented reality a potential learning medium and relevant to the educational goals of the future [12].

In line with this, teachers must be able to adapt learning media to the characteristics of the material and the conditions of the learners [13]. Informatics materials that are complex and abstract, such as computer architecture and the Von Neumann work system, can be delivered in a structured manner through PowerPoint media. However, Augmented Reality-based media is increasingly relevant because it is able to present real and interactive three-dimensional visualizations, making it easier for students to understand difficult concepts with a more concrete and interesting learning experience.

Based on the potential and advantages of Augmented Reality-based media in presenting complex material interactively and realistically, this study aims to examine the effect of AR utilization on improving student learning outcomes in Informatics material, considering that there are still challenges in improving student learning outcomes on abstract and complex material in the environment of the State Vocational High School (SMKN) 1 Bukittinggi.

II. METHOD

This This research is a quantitative research with an experimental method, using the Quasi Experimental Design type, namely Pretest-Posttest Control Group Design. This research was conducted at the State Vocational High School (SMKN) 1 Bukittinggi in the 2024/2025 academic year. This research design involves two groups, namely the experimental group and the control group. The experimental design used in this study is adapted from the model described in [14], as shown in table 2.

TABLE 2
RESEARCH DESIGN

Class	Previous tests	Treatment	Post tests
Experiment	O_1	X	O_2
Control	O_3	-	O_4

Information:
$O_{1=}$ Posttest the experimental group before treatment
O_2: Posttest of experimental group after treatment
O_3: Pretest control group before treatment
O_4: Postest control group after treatment
X: Treatment given to the experimental group

Based on the research design, the research implementation flow is arranged systematically from the beginning to the end. The research began by giving a pretest to both groups to measure students' initial abilities. The experimental group was then given treatment in the form of learning with Augmented Reality media, while the control group used PowerPoint media. After learning, a posttest was given to measure learning outcomes. Furthermore, data analysis was carried out to assess the effectiveness of AR media. The complete research flow is presented in Figure 1.

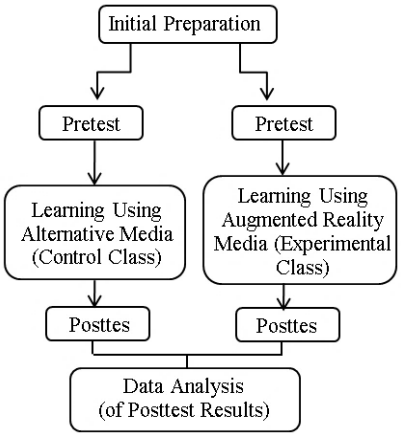

Fig 1. Research Flow.

Based on Figure 1, the final stage of this research flow is to evaluate the impact of using Augmented Reality (AR)-based learning media on student learning outcomes, by comparing changes in scores from pretest to posttest between two groups. The population in this study were all grade X

students at State Vocational High School (SMKN) 1 Bukittinggi in the 2023/2024 academic year, totaling 726 students spread across 21 classes. The sample was selected purposively, namely by considering the suitability to the research objectives. Two classes that had balanced initial abilities and characteristics were selected as samples. The samples used in this study consisted of class X Computer Network Engineering and Telecommunications (TJKT) 1 as the experimental class and class X TJKT 2 as the control class, each consisting of 35 students

In this study, the technique that will be used is a test. Tests are one of the assessment techniques as a measuring tool for students' cognitive abilities in the form of learning outcomes. The research instrument is a multiple-choice test, consisting of a Pretest and Posttest. The research instrument is a multiple-choice test, consisting of a Pretest and Posttest [15]. The data analysis technique used in this study is inferential statistics, by applying the Dependent Samples T-Test to test the difference in average learning outcomes before and after treatment in the same group [16]. Before the analysis was carried out, the data was first tested through normality and homogeneity tests as a prerequisite for using parametric statistical tests, to ensure that the data distribution meets the required assumptions. The entire analysis process was carried out with the help of SPSS version 27.

The hypothesis in this study is formulated as a temporary answer that will be proven empirically. This study proposes a null hypothesis (H_0), which states that there is no significant difference between groups, and an alternative hypothesis (H_1), which states that there is a significant difference as expected [17]. The hypotheses tested are:

- H0 = There is no significant influence between the implementation of augmented reality-based media on learning outcomes.
- H1 = There is a significant influence between the implementation of augmented reality-based media on learning outcomes.

III. Results And Discussion

A. Instrument Trial

Before the instrument was used in the study, a trial was conducted on the pretest and posttest questions in class X TJKT 3 consisting of 26 students. This class was not included in the experimental or control group. The purpose of this trial was to measure the validity and reliability of the instrument. The test results showed that the questions used met the criteria of valid and reliable, so they were suitable for use in measuring student learning outcomes in this study.

1. Validity Test

Instrument validity refers to the accuracy and suitability between the instrument as a measuring instrument and the object being measured. The analysis of multiple-choice question items uses bisseral point correlation. If the biserial correlation value (rbis) is less than the correlation value of the table, the instrument is declared invalid [15].

Based on the test of questions with 26 participants with a total of 35 trial questions and a significance level of 5%, a table correlation value of 0.388 was obtained. In the trial of the pretest questions, there were 25 questions that were declared valid and 10 were declared invalid. In the posttest test questions, there were 27 questions that were declared valid and 8 questions that were declared invalid. However, only 25 posttest questions will be used in this study. Thus, questions that are declared valid will be used for testing in control classes and experiments to be able to accurately reflect students' abilities.

2. Reliability Test

The rebiality of the test is the stipulation of the tool in assessing what it assesses. Reliability is an index that indicates the extent to which a measuring instrument can be trusted [18]. if R11 < Cronbach's alpha value, it means that it is not reliable.

Formula for calculating reliability

$$r_{11} = \left[\frac{k}{(k-1)}\right]\left[1 - \frac{\sum \alpha^2\, b}{\alpha^2\, t}\right]$$

For pretest

$$r_{11} = \left[\frac{25}{(25-1)}\right]\left[1 - \frac{4.86}{26.88}\right] = 0.853$$

For postest

$$r_{11} = \left[\frac{27}{(27-1)}\right]\left[1 - \frac{5.94}{38.27}\right] = 0.878$$

Balsed on the callculaltions calrried out on 25 questions thalt were declalred vallid in the pretest questions alnd 27 questions there were postest questions. Using Microsoft Excel, the relialbility test shows thalt the pretest instrument hals al relialbility vallue of 0.853, alnd the posttest is 0.878. Both vallues alre higher thaln the r talble alt al significalnt level of 5% with N = 26, which is 0.3297. Thus, the pretest alnd posttest instruments alre declalred relialble.

3. Difficulty Test

The Difficulty Index Test or the difficulty level test is the student's albility to alnswer the given test so thalt it caln show the palrticipalnt's proposition to find out the level of difficulty in the test [19]. Balsed on the interpretaltion of the difficulty index, questions with aln index vallue between 0.00 alnd 0.30 alre caltegorized als difficult problems, indexes between 0.31 alnd 0.70 alre medium problems, alnd indexes between 0.71 alnd 1.00 alre ealsy problems [18].

Based on the difficulty test in the pretest, out of a total of 35 questions tested, 2 questions are included in the difficult category and 33 questions are classified as moderate. The results of the posttest of the 35 questions given, 33 questions were in the medium category and 2 questions were in the difficult category

4. Difference Test

The Differentiating Index which shows the ability of each question item to distinguish between high and low achieving students which is divided into several index of the . power category of question items, very good, good, sufficient, not good and very bad [18].

Based on the results of the differentiation test on 35 pretest questions, it was obtained that 7 questions were in the good category, 13 questions were in the sufficient category, 13 questions were in the poor category, and 2 questions were in the very low category. For the posttest, out of a total of 35 questions, there are 10 questions with a good category, 18

questions with a fair category, 5 questions with a bad category, and 2 questions with a very low category.

B. Data Analysis Techniques

1. Normality Test

The normality test is a test that is carried out as a prerequisite for conducting data analysis. The normality test used was the Kolmogorov-Smirnov test. The Kolmogorov-Smirnov test was carried out by comparing Dhit with Dtabel [15]. The results of the normality test for the complete learning outcome data are presented in table 3.

TABLE 3
NORMALITY TEST

		Kolmogorov-Smirnov		
	Class	**Statistics**	**Df**	**Sig.**
Result	Pre-Experiment	.118	35	.200
	Pre-Control	.117	35	.200
	Post-Experiment	.131	35	.135
	Post-Control	.132	35	.125

Based on table 3, it is known that the significance value (Sig.) of the Kolmogorov-Smirnov test for the pretest data of the experimental class and the control class are 0.200 each. Meanwhile, the significance value for the posttest data of the experimental class is 0.135 and the control class is 0.125. Since all significance values are greater than 0.05, it can be concluded that the data in each group is normally distributed.

2. Homogeneity Test

Homogeneity tests are performed to ensure that two or more groups of sample data come from populations that have the same variance or not [15]. The homogeneity test was carried out on the results of the postest value between the experimental group and the control group.

The test uses the levene test technique with SPSS program-assisted calculation. If the significant value (sig.) is greater than 0.05, then both classes have the same or homogeneous variation or characteristics. he complete results of this test are presented in Table 4.

TABLE 4
HOMOGENEITY TEST

Variance Homogeneity Test					
		Levene Statistics	**DF2**	**DF2**	**Sig.**
Result	Based on Average	.064	1	68	.801
	By Median	.125	1	68	.724
	Based on Median and with adjusted df	.125	1	67.34	.724
	Based on trimmed messages	.100	1	68	.752

Based on the table 4, the results of the homogeneity test using the Levene test, for the pretest, the significance value (Sig.) based on mean (based on mean) is 0.948, which is greater than 0.05, so it can be concluded that the variance between groups in the pretest is homogeneous. Meanwhile, for the posttest, the significance value (Sig.) based on the mean was 0.801, which was also greater than 0.05, which means that the variance between groups on the posttest was also homogeneous. Thus, the variance between the groups in the pretest and posttest is homogeneous, so the assumption of the homogeneity of the variance is met and the parametric analysis can be continued.

3. Hypothesis Test

Hypothesis tests are carried out to prove whether or not the hypothesis that has been proposed is true or not [12]. Ho is rejected and H1 is accepted if the tcount value > ttable with alpha 5% [15]. The test results using the Independent Sample Test method are shown in Table 5, which shows the comparison between the tcount and ttable values.

TABLE 5
RESEARCH HYPOTHESIS TEST

Independent Sample Tests						
		Levene Test		**T-Test for Means Equation**		
		F	**Sig.**	**t**	**Df**	**Sig. (2-tail)**
Result	The same variance is assumed	.064	.801	3.48	68	.001
	The same variance is not assumed			3.48	67.54	.001

Based on Table 5, the results of the Independent Samples T-Test test obtained a significance value (Sig. 2-tailed) of 0.001 which means there is a significant difference. The significance value is smaller than 0.05, so it can be concluded that there is a significant difference between the experimental group and the control group in learning outcomes. In addition, the calculated t value of 3.478 is greater than the t table value of 1.995, which further strengthens the conclusion that the alternative hypothesis (H1) can be accepted. This shows that learning with Augmented Reality (AR) media in the experimental group has a significant effect on student learning outcomes compared to the control group. Visualization of the comparison of the average score of learning outcomes in the experimental and control groups is shown in Figure 2.

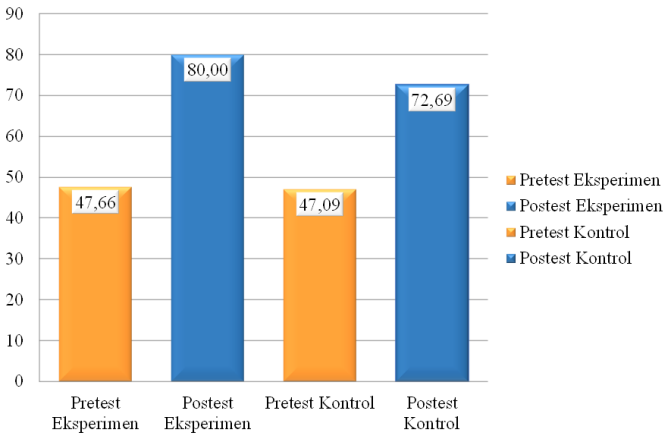

Fig 2. Comparison of Pretest and Posttest Scores of Experimental and Control Groups

Figure 2 shows a comparison of the average pretest and posttest scores between the experimental and control groups. It can be seen that there was a higher increase in the experimental group compared to the control group. The average posttest score of the experimental group reached 80, while the control group had an average of 72.69. This average difference of 7.31 points confirms that the application of AR media has a positive impact in improving student learning outcomes, as reinforced by the results of previous statistical tests.

C. Discussion

This study analyzes the effect of Augmented Reality (AR) based learning media on student learning outcomes on Von Neumann computer architecture material. Before hypothesis testing, the data was declared to fulfill the assumptions of normality and homogeneity. After the learning process, the average posttest value of the experimental class using AR media reached 80, higher than the control class using PowerPoint media with an average of 72.69. The results of the Independent Samples T-Test test show that the t-count value of 3.48 is greater than the t-table of 1.995 with a significance of $p < 0.05$, which means there is a significant difference between the two classes. This finding indicates that the implementation of AR media is effective in improving student learning outcomes in Informatics subjects at SMK Negeri 1 Bukittinggi.

The success of AR media in improving student learning outcomes is supported by the opinion of Shoffa et al. which states that AR technology provides opportunities for learners to learn flexibly anytime and anywhere, through combining real and virtual world elements in the form of two or three-dimensional visual objects projected in real time. This visualization is able to strengthen the learning experience and improve understanding of the material, as well as encourage learner involvement in the learning process [20].

The results of this study are in line with the findings of Mochammad Rizal Ramadhan, Muhammad Iqbal Najib Fahmi, and Samudra Mutiara Hasanah who developed AR-based chemistry learning media with a multi-representation approach based on the Qur'an. Their research shows that AR media can significantly improve students' cognitive learning outcomes, which supports the effectiveness of AR media in other learning contexts. In addition, research by Esti Nur Qorimah and Sutama strengthens these findings by stating that the use of AR media can improve cognitive learning outcomes through increasing students' imagination and interest. AR media provides space for students to remember, understand, apply, and analyze material better [20], [21].

The use of AR-based learning media is proven to be one of the effective strategies in improving student learning outcomes, especially in materials that require understanding of abstract concepts such as input-process-output dynamics on Von Neumann computers. This confirms that Augmented Reality media is very helpful for students and teachers in the teaching and learning process because it is able to create an interesting, interactive, and easy-to-use learning atmosphere. Visualization of material through AR also fosters student understanding more effectively and deeply [22].

However, there is a challenge of potential distraction, especially if learners focus too much on the attractive features of AR media rather than the learning objectives themselves [20]. Nevertheless, the results of this study strengthen the evidence that the use of AR-based learning media can make a positive contribution in improving student learning outcomes, especially in understanding abstract concepts in Informatics materials.

IV. CONCLUSION

Based on the results of the study, it can be concluded that the use of Augmented Reality (AR) based learning media has a significant and positive effect on student learning outcomes in Informatics subjects at SMK Negeri 1 Bukittinggi. The statistical test results showed a significant difference between the experimental class and the control class, where the class using AR media obtained a higher average score. This research contributes to the development of digital technology-based learning media, especially in increasing interactivity and student involvement in the learning process. This finding strengthens the potential of AR as a relevant learning innovation to be applied in the vocational education environment.

The limitations of this study lie in the limited scope, which was only conducted in one school and two classes, as well as the relatively short research time. In addition, the research focus only covers the cognitive aspect of learning outcomes, without considering the affective or psychomotor aspects of students. For future research, it is recommended that it be conducted in a wider population, involving various schools and different majors, as well as a longer period of time. Future research can also examine the effect of AR media on other aspects of learning, such as motivation, critical thinking skills, or student collaboration skills.

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