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THE INFLUENCE OF AUGMENTED REALITY (AR) BASED DIGITAL LEARNING MEDIA ON STUDENTS' COGNITIVE ABILITIES IN ATOMIC STRUCTURE MATERIAL

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Abstract

This research is motivated by the use of Augmented Reality media which is rarely used in learning, so that student learning outcomes using Augmented Reality media are still relatively low. This type of research is a quasi-experimental study with a non-equivalent control design. The purpose of this study is to determine the effect of Augmented Reality-based digital learning media on students' cognitive abilities in atomic structure material. This research was conducted in the 2024/2025 academic year at SMA Negeri 12 Pekanbaru with the main material Atomic Structure. The instruments used in this study were multiple-choice objective tests and non-test instruments in the form of questionnaires. Based on the analysis of test data, the results showed that there was a significant influence of the use of Augmented Reality-based learning media on students' cognitive abilities in atomic structure material. This is based on the results of hypothesis testing using the t-test on Posttest data. The results of the Posttest study showed a significance value (2-tailed of 0.00 < 0.05, thus indicating a significant difference between the experimental class and the control class. The average N-gain of students' learning outcomes in the experimental class was 15% and was categorized as high, while in the control class it was 45% and was categorized as moderate. The cognitive abilities of experimental group students were also superior in the cognitive domains of levels C2, C4 and C5. Furthermore, based on the analysis of non-test data, it can be concluded that overall the application of Augmented Reality-based learning media in learning atomic structure chemistry received a good response.
Keywords: learning media, augmented reality, cognitive ability, atomic structure

INTRODUCTION

Learning media serves as a tool for teachers in delivering subject matter, stimulating student creativity, and increasing student focus during the learning process. The presence of learning media can also increase student motivation, develop communication skills, and expand their imagination. This makes the teaching and learning process more effective and efficient, and strengthens interactions between teachers and students. Furthermore, learning media can help overcome boredom that may arise during classroom learning [1].

Learning media acts as a link between teachers and students during the learning process, providing an easier way for students to receive information and being a tool that helps in delivering learning materials during the teaching process, aiming to make it easier for students to understand the achievement of predetermined learning objectives and create entertaining learning activities.

Factors significantly influence engaging learning activities. One example is the use of learning media and technology, which must be engaging and interactive for students while maintaining the core content of the material being presented. To enhance the effectiveness of good learning activities, effective learning media sources are essential [2]. Therefore, teachers need to be skilled at selecting engaging learning media to help students learn more effectively.

The use of media in learning helps overcome the limitations of educators in conveying

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information and limited learning time in the classroom. The media acts as a source of information about teaching materials and as a source of practice that can come from various learning media based on current technological developments. The use of this media can have a significant impact on students' cognitive abilities [3, 4]. What makes students experience learning difficulties is reflected in various obstacles that hinder the achievement of students' cognitive abilities. These various obstacles can ultimately lead to achievement that does not meet expectations, for example in chemistry subjects that are difficult for students because chemistry contains abstract concepts and high conceptual interconnections [3]. This is also evident from the results of the author's interview with one of the chemistry teachers at SMAN 12 Pekanbaru, the media frequently used in the teaching and learning process are power point, flash media and canva and AR (Augmented Reality) application trials have been conducted in a short time.

In this modern era, the use of digital technology is increasing, with everyone relying on it to facilitate all tasks, including education. The increasing number of vocational high schools is evidence of the increasing use of educational technology in Indonesia [5]. Therefore, teachers' use of technology in the teaching process can facilitate the delivery of messages through learning media.

The most frequently used learning media is PowerPoint presentations, which contain only text and images with many slides that are difficult for students to understand. This makes students bored with learning and results in low student learning outcomes. The problem faced at SMAN 12 Pekanbaru prompted researchers to look for learning media that would facilitate the learning process other than using PowerPoint. One such medium is the use of Augmented Reality (AR) media. The application of AR media is useful for increasing interactivity and effectiveness, which can be widely implemented in various other media. The use of AR in learning can provide students with a collaborative and in-depth learning experience. By combining virtual elements with real-life environments, AR can help students visualize complex ideas more easily [6]. Currently, technological developments in the field of education continue to grow. One example is the application of Augmented Reality for learning media that helps in arranging the placement of items in the laboratory [7].

The influence of Augmented Reality-based media has numerous benefits that can be applied in various fields, including education. This technology enables the delivery of information that is more easily understood by users, making it suitable for developing learning applications that support the teaching and learning process. One example is chemistry learning about atomic structure [8].

METHOD

This research uses a quantitative method with a Research and Development (R&D) approach. The R&D method aims to develop and validate the resulting product. The development model used is the ADDIE model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation. *However,* this research is limited to the Implementation stage.

This research was conducted in August-September of the 2024/2025 academic year according to the schedule set by the school, and the research location was at SMAN 12 Pekanbaru. The research subjects were 10th-grade students of SMAN 12 Pekanbaru, consisting of classes X7 and X8, with a total of 80 students. Class X8 served as the experimental class, and class X7 served as the control class. The research objective was the effect of using Augmented Reality (AR)-based digital learning media on students' cognitive abilities in atomic structure.

The instruments used in this study were tests using ABCD-based test questions, questionnaire-based notes, and interviews. Before developing multiple-choice questions using AR-based media, the researchers searched for several literature studies on atomic structure. The results will be presented in a table. Next, the researchers conducted pretests and posttests to analyze the results on a number of students.

After the questions were compiled, validation was carried out by a chemistry education validator lecturer from Riau University and one chemistry education lecturer from Sultan Syarif Kasim State Islamic University, Riau. After being declared valid by the validator, The researcher conducted a large-scale validity test on the research data results, namely 84 students from SMAN 12 Pekanbaru.

The data collection techniques used in this study were tests, non-test methods, and interviews. Tests were conducted to measure students' learning outcomes, non-test methods were used to obtain supporting data related to the learning process, and interviews were carried out to gain deeper information about students' experiences and responses during the learning activities.

To analyze the data, several psychometric tests are required with several test techniques, namely:

1. Validity test.

   The validity test was conducted to determine the level of validity of the research instrument used. A research instrument is considered valid if it is able to measure the intended variables accurately and reveal data from the variables being studied appropriately. One way to test the validity of test items is to use the Pearson Product Moment formula.

$$r_{xy} = \frac{N(\sum xy) - (\sum x).(\sum y)}{\sqrt{\{N.\sum x^2 - (\sum x)^2\}}.\{N.\sum y^2 - (\sum y)^2\}}$$

   Information:
   r xy = Correlation coefficient
   ∑x = Total item score
   ∑y = Total number of items
   N = Number of students

   The calculated r and r table values are then compared. If the calculated r obtained from the formula above is greater than the r table, then the question item is considered valid; if not, then the question item is invalid [9].

2. Reliability test

   In evaluating reliability, researchers used the KR-20 reliability test to ensure the instrument was trustworthy, by eliminating or replacing invalid items. Here is the KR-20 Kuder Richardson formula we use.

$$r_{11} = \left(\frac{n}{n-1}\right)\left(\frac{S^2 - \sum pq}{S^2}\right)$$

   Information:
   r11 = Reliability of questions with the KR-20 equation
   p = Percentage of correct answers to question 1
   q = Percentage of wrong answers to question 1
   (q=1-p) pq = The result of multiplying p and q
   N = Number of items
   S = Standard deviation (square root of variance)

3. Test the level of difficulty

   This test is used to assess whether a question can be categorized as easy or difficult. The difficulty level of a question is calculated using the Du Bois formula:

$$P = \frac{B}{JS}$$

   Information:
   P = Difficulty index
   B = Number of students who answered correctly
   JS = Total number of students

4. Test of the difference in power of questions

   The discriminating power calculation aims to separate students who understand the material from those who do not by distinguishing between the different abilities of the questions given. The following is the discriminating power formula according to Arikunto:

$$DP = - = -\frac{B_A}{J_A}\frac{B_B}{J_B} P_a P_b$$

   Information:
   J = Number of people taking the test
   JA = Number in the high category
   JB = Number of people in the low category
   BA= Number of people in the high category who answered correctly

BB= Number of people in the low category who answered correctly
Pa = Percentage of those who follow the high category and answer correctly
Pb = Presentation that followslow category answered correctly

RESULTS AND DISCUSSION

This study aims to determine the effect of using Augmented Reality (AR)-based learning media on students' cognitive abilities in atomic structure material. The study was conducted on 80 students of class X of SMAN 12 Pekanbaru in the 2024/2025 academic year. Class X8 was used as the experimental class and class X7 as the control class. The research data were obtained through pretests and posttests which were then analyzed to answer the research hypothesis.

Normality test

The results of the normality test showed that the pretest and posttest data in both the experimental and control classes were normally distributed, with a significance value greater than 0.05. Therefore, the data met the requirements for parametric statistical analysis. These results indicate that the research data came from a population with a normal distribution and can therefore be used for hypothesis testing.

The normality test in this study was conducted using SPSS version 25.0 using the Kolomogorov-Smirnov test. Data were considered normally distributed if the Kolomogorov-Smirnov test yielded a significance value (sig.) of 0.05. The pretest normality results for the experimental and control classes are presented in the following Figure 1.

TES NORMALITAS PRETES

Kelas	Kolmogorov-Smirnov[b]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	Df	Sig.
Eskperimen	.232	13	.054	.810	13	.009
Kontrol	.232	13	.054	.810	13	.009

Figure 1. Pretest Normality Test

Based on the results of the normality test of the pretest data of students using the Kolmogorov-Smirnov test, a significance value of 0.054 was obtained for the experimental class and 0.54 for the control class. These results indicate that both groups of data distribution are the same in the experimental and control classes. The data distribution of 0.054 shows that the experimental class and the control class are normally distributed presented in Figure 2.

TEST NORMALITAS POSTTES

Kelas	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	Df	Sig.
Eskperimen	.136	40	.062	.939	40	.033
Kontrol	.136	40	.059	.934	40	.021

Figure 2. Posttest Normality Test

The results of the normality test of the posttest data show a significance value of 0.062 for the experimental class and 0.059 for the control class. These values are also greater than 0.05, indicating that the posttest data are normally distributed.

These results indicate that the research data meets the requirements for parametric statistical analysis. The normal distribution of the data indicates that student abilities in both classes are fairly distributed and do not exhibit any deviations that could affect the results of the statistical analysis.

Homogeneity Test

Homogeneity testing was also conducted on both pretest and posttest data from both the experimental and control classes. The results of the homogeneity test calculations using descriptive statistical techniques can be obtained with the help of SPSS version 25.0. The basic guidelines for decision-making in the homogeneity test are as follows.

If the significance value or sig. < 0.05, it indicates that the variance of two or more data samples is not the same (not homogeneous).

If the significance value or sig. > 0.05, it indicates that the variance of two or more data samples is the same (homogeneous). The pretest homogenity results is presented in the following Figure 3.

TEST HOMOGEN PRETES

		Levene Statistic	df1	df2	Sig.
Hasil Pretes	Based on Mean	.521	3	71	.669

Figure 3. Homogeneous Pretest Test

Based on the homogeneity test results on the pretest data, a significance value of 0.669 was obtained. This value is greater than 0.05, indicating that the pretest data for both classes had homogeneous variance. Furthermore, the homogeneity test results on the posttest data showed a significance value of 0.338, which is also greater than 0.05, indicating that the posttest data for both classes were homogeneous presented in Figure 4.

TEST HOMOGEN POSTTES					
		Levene Statistic	df1	df2	Sig.
Hasil Posttes	Based on Mean	.929	1	78	.338

Figure 4. Homogeneous Posttest Test

These results indicate that the experimental and control classes had relatively similar characteristics before the treatment. Therefore, the differences in learning outcomes that emerged after the treatment can be attributed to the use of different learning media, namely Augmented Reality in the experimental class and conventional learning in the control class.

Research Hypothesis Testing

The final data analysis to test the research hypothesis is to determine the differences and improvements in student learning outcomes using Augmented Reality on atomic structure material. After conducting the data analysis requirements test and it is known that the data is normally distributed, it is known that the data are normally distributed, it is known that the data obtained are a type of parametric statistics. The results of the research can be proven by the t-test and the N-gain test as follows:

1. t-Test

Data analysis using SPSS can be performed using the independent sample t-test method to test differences in student learning outcomes between the experimental and control classes. Data are considered significant if the significance value is less than the 5% level. The results of the t-test calculations for the experimental and control classes are presented in the following Figure 5.

Independent Samples Test						
	Levene's Test for Equality of Variances					
	F	Sig.	t	df	Sig. (2-tailed)	Keterangan
Hasil	21,240	0,000	3,740	78	0,000	Sig. (2-tailed) > (ada perbedaan signifikan

Figure 5. t-Tes

The results of the independent sample t-test showed a significance value (2-tailed) of 0.000. Because the significance value is less than 0.05, H_0 is rejected and H_a is accepted. This indicates a significant difference between student learning outcomes in the experimental and control classes.

This difference indicates that the use of Augmented Reality media has an impact on students' cognitive abilities in atomic structure. AR media helps students understand abstract concepts through three-dimensional visualizations, making the material easier to grasp. These results align with research by [8], which states that Augmented Reality can improve conceptual understanding in chemistry learning.

2. N-Gain Test

The normal gain (N-Gain) test is used to show the increase in students' understanding or mastery of concepts after learning. The following is the average N-Gain value of the experimental class and the control class presented in Table 1.

Table 1. N-Gain Test

N-Gain Score	Category	Experiment Class		Control Class	
		Ts	Percentage (%)	Ts	Percentage (%)
$g > 0.7$	High	6	15	12	30
$0.3 \leq g$	Medium	33	82.5	18	45
$g > 0.3$	Low	1	2.5	10	25
Amount			100		100

Based on the N-gain test calculations presented in the table above, it can be seen that the N-gain across the sample classes differed significantly. In the high category, the experimental and control classes had a 15% difference, with the experimental class having a higher percentage. Furthermore, the N-gain difference in the medium category was 37% With the control class having a higher percentage, and the N-gain difference in the low category was 22.5%, with the experimental class having a higher percentage. The N-Gain calculation results show that the average N-Gain for the experimental class was 55.7%, categorized as moderate, while the control class was 48.7%, categorized as moderate. Although both classes were in the same category, the N-Gain for the experimental class was higher than that of the control class.

This shows that the use of Augmented Reality media is more effective in improving students' cognitive abilities than conventional learning. Interactive visualizations make it easier for students to grasp the abstract structure of atoms, resulting in improved conceptual understanding after learning.

3. Student Learning Improvement Results

Student learning outcomes were measured using an objective test method consisting of a pretest and posttest with the aid of Microsoft Excel. The test results can be seen in the following Table 2.

Table 2. Learning Improvement Results

Information	Experiment Class		Control Class	
	Pre	Post	Pre	Post
Highest score	75	100	50	87.5
Lowest Score	37.5	62.5	37.5	0
Average	52.5	79.7	41.1	70

The results showed that the average posttest score for the experimental class was 79.6, while the average posttest score for the control class was 70. This difference indicates that student learning outcomes in the experimental class were higher than those in the control class.

The improved learning outcomes in the experimental class occurred because Augmented Reality provided a more engaging and interactive learning experience. Students could see a visual representation of atomic structure, making it easier to understand the material compared to using only conventional learning media. The results of the pretest and posttest are shown in Figure 6.

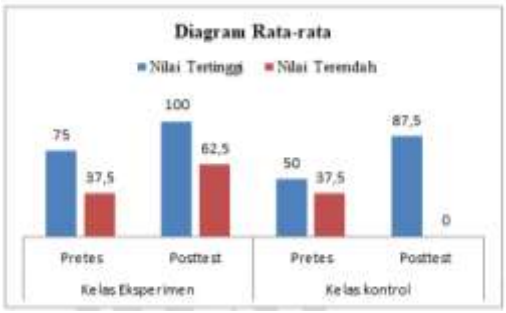


Figure 6. Average Chart

4. Cognitive Thinking Abilities of Experimental Class and Control Class

The learning outcomes of students in the experimental class and control class based on cognitive level can be seen in the following Figure 7.

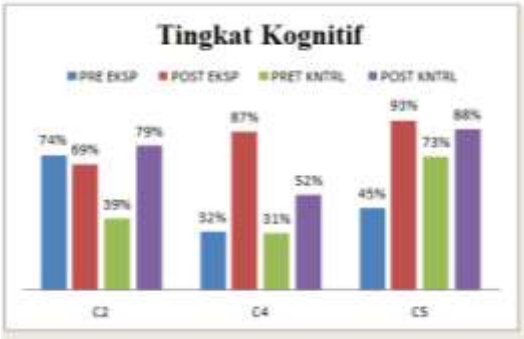


Figure 7. Cognitive Level

The analysis results based on cognitive levels indicate that students' abilities improved in each indicator after the learning process. The most significant

improvement occurred at level C2 (understanding), indicating that students were increasingly able to explain and grasp the concept of atomic structure.

The improvement in understanding indicates that Augmented Reality media helped students develop a deeper understanding of concepts. Visualizing objects in three dimensions allows students to connect abstract concepts with more concrete representations, making the learning process more meaningful.

5. Interview Result Data

The researcher conducted a sequence of analyses on only 2 selected students because this study used a specific sampling technique that was adjusted to the research objectives. The selection of these two students was based on several predetermined criteria, such as the students' ability levels, learning outcomes, activeness during the learning process, and suitability with the research data requirements.

CONCLUSION

Based on the results of data analysis, the use of Augmented Reality (AR) learning media has a significant effect on students' cognitive abilities in atomic structure material. This is indicated by the results of the t-test which obtained a Sig. (2-tailed) value of 0.000 (<0.05), so that H_0 is rejected and H_a is accepted. These results are supported by posttest data which show that student learning completeness in the experimental class reached 100%, higher than the control class which reached 87.5%. Thus, Augmented Reality (AR) learning media is effective in improving students' cognitive abilities in atomic structure material.

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