EDUMATSAINS
JURNAL PENDIDIKAN MATEMATIKA DAN SAINS
E-ISSN:2527-7235
Volume 11 Issue. 1, July 2026, pp 68-81
http://ejournal.uki.ac.id/index.php/edumatsains

The Effect of Using Augmented Reality (Ar) Media on Students' Conceptual Understanding

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Article Info

Article history:
Received: May 30th, 2026
Revised: July 7th, 2026
Accepted: July 9th, 2026
Available online: July 31st, 2026

https://doi.org/10.33541/edumatsains.v11i1.8214

Abstract

This research seeks to explore the impact of implementing Augmented Reality educational tools at SMK Raudlatul Uluum Aek Nabara among the XI TB and XI TKJ students on their grasp of concepts. The research employs a quantitative methodology with a quasi-experimental framework, involving two classes: an experimental group and a control group. The experimental group received instruction through Augmented Reality tools, whereas the control group followed traditional instructional strategies. Data was gathered through pretests, posttests, and student feedback questionnaires. The collected data underwent analysis through normality assessments, homogeneity evaluations, N-Gain tests, and hypothesis verification using the t-test. The findings reveal that the incorporation of Augmented Reality tools significantly enhances students' conceptual comprehension.

Keywords: Augmented Reality, Conceptual Understanding, Learning Outcomes, Mathematics, Interactive Media

1. Introduction

Mathematics education is a crucial and irreplaceable intellectual foundation in shaping a logical, analytical, and systematic framework of thinking in learners at every level of education; these abilities are inherently the primary prerequisites for successfully navigating the complexities of science, technology, engineering and mathematics (STEM), as well as driving innovation across various sectors of modern life (Fefy Gusmarlia, 2025). Mathematics offers numerous benefits in everyday life, namely by training ways of thinking, enabling problem-solving, assisting in buying and selling activities, and developing skills (Yusron et al., 2023).

Augmented Reality (AR) was chosen for this study because it possesses advantages not found in most other digital media. Media such as PowerPoint, images, or educational videos generally present information only in two dimensions and are passive in nature, meaning that pupils act merely as recipients of information. In contrast, AR is capable of combining three-dimensional virtual objects with the real environment in real time and enables pupils to interact directly with learning objects. These characteristics provide a more concrete and immersive learning experience, thereby helping students visualise abstract concepts in matrix material, such as the structure of rows and columns, the position of elements, and matrix operations. Consequently, AR is considered more suitable for supporting conceptual understanding than digital media that merely present information statically (Gusteti et al., 2023).

This study focuses on the matrix curriculum for Year 11 at SMK Raudlatul Uluum Aek Nabara. The matrix curriculum is one of the topics in mathematics that often poses difficulties for students due to its abstract nature and the fact that it is presented in the form of symbols, numbers and interrelated rules of operation. Many students struggle to distinguish between basic matrix concepts, such as rows, columns, order and element positions, which leads to errors when performing operations such as addition, subtraction, multiplication and matrix transposition. These difficulties generally arise because teaching is still dominated by the verbal and symbolic presentation of material, meaning that pupils tend to memorise solution procedures without understanding the relationships between the underlying concepts (Maria et al., 2023).

Although various studies have shown that Augmented Reality (AR) media can enhance students' learning motivation, interest in learning, and learning outcomes in mathematics, there are still several aspects that have not been studied in depth. Most previous studies have focused more on improving general learning outcomes or aspects of learning motivation, whilst research specifically examining the impact of AR media on the understanding of mathematical concepts remains relatively limited. Yet, conceptual understanding is a fundamental ability that determines students' success in connecting mathematical ideas, applying concepts in various situations, and solving problems accurately (Dicky et al., 2025).

Based on a review of the theory and previous research findings, this study is grounded in the hypothesis that the use of Augmented Reality (AR) media has a positive effect on students' understanding of matrix concepts. The three-dimensional visualisation and interactivity offered by AR media are expected to help students understand abstract concepts in matrix material, such as row and column structures, order, element positions, and matrix operations, thereby resulting in better conceptual understanding compared to conventional learning.

This study is based on the assumption that the key characteristic of Augmented Reality (AR) technology—namely, the ability to visualise virtual objects interactively—can help students understand the abstract concepts of matrices. In conventional learning, matrix concepts are generally presented in the form of symbols, numbers and calculation procedures, so that students often find it difficult to distinguish between rows and columns, determine the order of a matrix, understand the position of elements, and follow the process of matrix operations. These conditions mean that students' understanding tends to be procedural and lacks depth.

Consequently, the research hypothesis is formulated as follows:

H_0 (Null hypothesis): There is no significant effect of the use of Augmented Reality (AR) media on students' understanding of matrix concepts.

H_1 (Alternative hypothesis): There is a significant effect of the use of Augmented Reality (AR) media on students' understanding of matrix concepts.

2. Methods

This study employs a positivistic quantitative paradigm that emphasizes the objective measurement of observable variables to establish casual relationships through statistical hypothesis testing, using a quasi-experimental design of the nonequivalent control group type, which is methodologically appropriate for controlling confounding variables in a non-randomized whole-class educational context. This design allows for a valid comparison between the experimental group receiving the innovative *Augmented Reality* (AR)-based treatment and the control group using the conventional approach, through a cycle of initial measurement (pretest), differential intervention, and final measurement (posstest), there by minimizing selection bias and ensuring the generalizability of findings to a population of vocational high school students with similar characteristics.

The key characteristic of the Augmented Reality (AR) medium used in this study is its ability to present interactive visualisations of matrix objects via mobile devices. According to the research procedure, students in the experimental class used an AR application to visualise matrix concepts during the learning process, whilst the control class used conventional methods consisting of lectures and PowerPoint presentations. This visualisation enables pupils to observe a more concrete representation of matrices compared to the presentation of mathematical symbols in conventional teaching, thereby making concepts such as matrix order, rows, columns, matrix elements and matrix operations easier to understand.

This study employed purposive sampling, a technique for selecting a sample based on specific considerations tailored to the research objectives. This technique was chosen because the research design used was quasi-experimental, meaning the researcher was unable to randomly assign students to the experimental and control groups.

Based on these criteria, one class was designated as the experimental class, which received instruction using Augmented Reality (AR) media, whilst the other class served as the control class, receiving conventional instruction. This arrangement was made so that differences in learning outcomes following the intervention would better reflect the influence of AR media use rather than differences in the learners' initial characteristics.

The intervention in the experimental class utilised Assemblr EDU, an Augmented Reality (AR)-based learning application accessible via Android devices. This application was selected because it is capable of presenting three-dimensional (3D) virtual objects in real time and supports interactive learning through the visualisation of abstract concepts. This study did not develop a new AR application but instead adopted Assemblr EDU as a platform to present

matrix material in the form of interactive three-dimensional visualisations. The researchers were responsible for designing and compiling the learning content for the matrix material on the Assemblr EDU platform to ensure it aligned with the learning objectives and the established indicators of conceptual understanding.

Learning in the experimental class began with the teacher explaining the learning objectives, the competencies to be achieved, and how to access and use the Assemblr EDU application. Subsequently, pupils accessed the learning resources via their smartphones by scanning a QR code or opening the link provided.

During the lesson, pupils interact directly with Augmented Reality (AR) objects displayed via the Assemblr EDU app on their smartphones. After accessing the material via the QR code or link provided, pupils observe the three-dimensional (3D) model of the matrix material that appears on their device’s screen. Pupils then explore the virtual object by rotating it, zooming in and out, and changing the viewing angle to observe the structure of the matrix more clearly.

To ensure consistency in the implementation of the intervention, lessons in the experimental class were conducted in accordance with the learning scenario that had been drawn up prior to the study. During the lessons, the teacher followed the established learning steps, ranging from introductory activities, exploration using the media, discussions, to evaluation. Students in the experimental class were given equal opportunities to use Assemblr EDU in accordance with the prescribed procedures.

The study was conducted during the second semester of the 2025/2026 academic year, specifically in January 2026, at SMK Raudlatul Uluum Aek Nabara as a representative site for the vocational education context in the rural areas of North Sumatra, with a population consisting of 60 eleventh-grade students who met the inclusion criteria based on the national curriculum, where the sample was determined using a rational purposive sampling technique by selecting two parallel classes-XI TB as the experimental group (n=30 students) and XI TKJ 1 as the control group (n=30 students).

The research variables consist of an independent variable, namely the application of *Augmented Reality* (AR) learning media operationalized as an experimental intervention on matrix material (definitions, orders, elements, addition operation, scalar multiplication, and applications), as well as a dependent variable, namely students' conceptual learning understanding measured multidimensionally within Bloom's revised cognitive domain (C1: recall through C6: creation), using a primary instrument consisting of a 10-item objective essay test designed based on a comprehensive rubric to capture holistic thinking processes-not merely rote recall-but rather the ability to restate concepts, identify elements, perform manipulative operations, and conduct applied analiysis reflecting the depth of conceptual understanding.

The research instrument, in the form of a matrix concept comprehension test, was developed based on established learning indicators and conceptual comprehension indicators. Prior to its use in the study, the instrument underwent a content validation process by a panel of experts comprising mathematics education lecturers and mathematics teachers. The validation process aimed to ensure that each test item was aligned with the competencies being measured, the learning material, and the research objectives. Feedback from the validators was used as the basis for revising and refining the instrument before it was pilot-tested.

Table of Instrument Characteristics

Conceptual Understanding Indicators	Content	Question Format	Number of Items	Question Number
Explain the concept of a matrix	Definition and elements of a matrix	Essay	1	1
Determining the order and elements of a matrix	Order and elements	Essay	2	2 – 3
Classifying types of matrices	Types of matrices	Essay	1	4
Applying matrix operations	Addition, transpose, multiplication	Essay	3	5–7
Analysing and evaluating concepts	Application of matrix concepts	Essay	3	8–10

Analytical Marking Scheme

Aspect	Result
Number of validators	3 people (2 lecturers, 1 maths teacher)
Expert validation results	Suitable for use following revision
Item validity range	0.45 – 0.82
Level of difficulty	2 easy, 6 moderate, 2 difficult
Discrimination index	3 good, 7 adequate

Reliability coefficient (Cronbach's Alpha)	0.87 (high)
Rating consistency	Using an analytical scoring rubric

The implementation procedure followed strict ethical and temporal protocols: initial orientation and simultaneous pretest for both groups to establish a baseline; an intervention consisting of 3 sessions (90 minutes per session), during which the experimental group used a mobile AR application for interactive 3D.

3. Result and Discussion

Prior to the intervention, an analysis of the pre-test scores was conducted to ensure that the initial abilities of pupils in the experimental and control groups were at an equivalent level. Thus, both groups had relatively equivalent initial abilities before the intervention was delivered, meaning that differences in post-test results following the learning process could be interpreted as a consequence of the differences in the treatments administered, namely the use of Augmented Reality media in the experimental group and conventional learning in the control group.

This investigation will present a comprehensive summary of the research findings gathered. The findings discussed include pre-assessment and post-assessment results, along with observation forms from both the experimental and control groups.

a. Pretest Results

Based on the pretest results obtained before the intervention, the data indicate that students' initial still vary considerably.

Table 1. Measures of Central Tendency and Dispersion of Pretest Data for the Experimental and Control Class

No	Statistic	Class Eksperimental	Class Control
1	Sample Size (N)	30	30
2	Minimum Score	45	43
3	Maxsimum Score	78	75
4	Mean	60,25	58,10
5	Median	60	58
6	Mode	55	57
7	Range	33	32
8	Variance	85,30	80,25
9	Standard Deviation	9,24	8,96

According to the data presented in the table above, the average pretest score for the experimental group was 60.25, while the control group scored 58.10. This reflects that the starting competencies of both classes were relatively similar. The standard deviation values for both classes were also relatively similar, indicating that the data distribution in both classes was fairly homogeneous.

b. Posttest Results

The posttest results, conducted after the intervention, show that the students' performance improved compared to the pretest results.

Table 2. Measures of Central Tendency and Data Dispersion for Posttest Results of the Experimental and Control Class

No	Statistic	Class Eksperimen	Class Control
1	Sample Size (N)	30	30
2	Minimum Score	65	60
3	Maksimum Score	95	88
4	Mean	82,40	75,30
5	Median	83	75
6	Mode	85	72
7	Range	30	28
8	Variance	64,20	70,15
9	Standard Deviation	8,01	8,38

According to the data presented in the table above, the average posttest score of the experimental group surpasses that of the control group. This suggests that the intervention provided to the experimental group positively influenced the enhancement of student learning results.. Furthermore, the standard deviation values for both classes are relatively similar, suggesting that the data distribution in both classes is fairly even.

c. Cognitive Thinking Skills

Cognitive thinking skills are an individual's ability to acquire, process, and use knowledge through cognitive functions like recalling, comprehending, utilizing, dissecting, assessing, and innovating.

Table 3. Pretest-Posttest Results by Cognitive Level

Level	Exsperimental Pretest	Exsperimental Posttest	Control Pretest	Control Posttest
C1 (Recall)	65	85	63	75
C2 (Comprehension)	60	83	58	73
C3 (Applying)	58	82	55	70
C4 (Analyzing)	55	80	53	68
C5 (Evaluating)	52	78	50	65
C6 (Creating)	50	76	48	63

The pretest data showed that the initial ability levels of the experimental group (mean = 60.25, SD = 9.24, min = 45, max = 78) and the control group (mean = 58.10, SD = 8.96, min = 43, max = 75) were comparable, confirming initial homogeneity. Posttest scores showed a significant increase in the experimental group (mean = 82.40, SD = 8.01, min = 65, max = 95) compared to the control group (mean = 75.30, SD = 8.38, min = 60, max = 88), with a highlights in the progress at the higher levels: C4 (analysis) increased by 25 points (experimental group) vs. 15 (control group), and C6 (creation) increased by 26 vs. 15 points.

Overall, these results indicate that the intervention had a positive effect on improving students' cognitive thinking abilities. Significant improvements at higher cognitive levels indicate that students are not only able to understand the material but also to process, analyze, and generate new ideas or solutions based on their existing knowledge.

d. Normal Gain (N-Gain) Test

The N-Gain assessment was performed to assess the enhancement in students' educational achievements following the intervention. According to the N-Gain computations, it was found that the average improvement in students' learning outcomes fell into the (low/moderate/high) categories. This indicates that the implemented learning approach was able to improve students' abilities in a (somewhat/fairly/very) effective manner.

Table 4. N-Gain Test Results

Exsperimental Class and Control Class

No	Class	Average Pretest	Posttest Mean	N-Gain	Category
1	Exsperimental	60,25	82,40	0,56	Moderate
2	Control	58,10	75,30	0,41	Moderate

According to the table presented above, the experimental group achieved an average N-Gain score of 0.56, placing it in the moderate range, while the control group recorded a score of 0.41, which similarly falls into the moderate range. Despite both groups being categorized the same, the N-Gain score of the experimental group surpasses that of the control group. This signifies that the enhancement in students' learning outcomes in the experimental group is superior to that in the control group. Therefore, it can be inferred that the applied treatment is more effective in advancing student skills.

e. Normality Test

A test for normality was performed to ascertain whether the collected data exhibited a normal distribution. The criterion for testing stated that if the significance level exceeded 0.05, the data would be deemed normally distributed; conversely, if the significance level fell below 0.05, the data would be regarded as not normally distributed.

Table 5. Results of the Chi-Square Normality Test for the Pretest and Post-Test for the Experimental and Control Classes

No	Data	Class	X^2 calculate	X^2 table (α = 0,05)	Notes
1	Pretest	Exsperiment	7,85	11,07	Normally Distributed
2	Pretest	Control	8,20	11,07	Normally Distributed
3	Posttest	Exsperiment	6,75	11,07	Normally Distributed
4	Posttest	Control	7,10	11,07	Normally Distributed

According to the table aforementioned, it is evident that the computed X^2 value for all datasets, including pretest and posttest in both experimental and control groups, is less than the tabulated X^2 value at a significance threshold of 0.05. Therefore, we can deduce that all datasets follow a normal distribution..

f. Homogenity Test

The homogeneity assessment is performed to evaluate if the variances of the data from multiple groups are equivalent (homogeneous) or otherwise. The homogeneity assessment is performed using the F-test (Fisher) to assess the equality of variances between two groups.

Table 6. Results of the Homogeneity Test

No	Data	Exsperiment Variance	Control Variance	Calculated F	Table F (α = 0,05)	Notes
1	Pretest	85,30	80,25	1,06	1,84	Homogeneous
2	Posttest	64,20	70,15	1,09	1,84	Homogen

According to the preceding table, the computed F-value for the pretest and posttest results is less than the F-value listed in the table at a significance threshold of 0.05. Therefore, one can infer that the variances of the data in both the experimental and control groups are consistent.

g. Hypothesis Test Results

A hypothesis examination was performed to assess if there was a notable impact between the variables being analyzed. According to the findings from the t-test computation, it was revealed that the computed t-value surpassed the critical t-value., so H0was rejected and H1was accepted.

Table 7. Hypothesis Test Calculation Results

No	Data	Exsperimental Mean	Control Mean	Calculated t	Table (α = 0,05)	Notes
1	Pretest	60,25	58,10	0,85	2,00	Not Significant
2	Posttest	82,40	75,30	2,75	2,00	Significant

Referring to the table above, the computed t-value for the pretest data is less than the critical t-value, leading to the conclusion that no significant distinction exists between the experimental and control classes prior to the treatment application. In contrast, the posttest data revealed that the computed t-value exceeded the critical t-value, resulting in the rejection of H0 and the acceptance of H1. This signifies a noteworthy difference in the learning outcomes between students in the experimental and control classes following the treatment. Therefore, it can be concluded that the administered treatment had a positive impact on enhancing student learning outcomes.

h. Results of the Questionnaire Data Analysis

Based on the results of the analysis of the questionnaire data provided to the respondents, it was found that the majority of respondents gave positive responses to the variables under study.

Table 8. Questionnaire Results on the Use of Learning Media Augmented Reality

No	Statement Indicators	Average Score	Percentage (%)	Category
1	Interest in AR media	4,30	86%	Very Good
2	Ease of use of AR media	4,10	82%	Good
3	Clarity of content display	4,25	85%	Very Good
4	Improves understanding of the material	4,35	87%	Very Good
5	Improving learning motivation	4,20	84%	Very Good
6	Interactivity in learning	4,28	86%	Very Good
7	Effectiveness of use in learning	4,18	83%	Good
8	Satisfaction with the use of AR media	4,32	86%	Very Good
	Overall Averange	4,25	85%	Very Good

From the provided table, it's evident that the feedback on the application of Augmented Reality learning tools belongs to the 'exceptionally good' category, achieving an average score of 85%. This suggests that students reacted extremely favorably to the incorporation of AR tools in their education, particularly regarding engagement, user-friendliness, and efficacy in enhancing comprehension of the subject matter.

4. Conclusion

Drawing from an extensive examination of the empirical findings from this research, it is evident that the implementation of Augmented Reality (AR) technology has a beneficial and noteworthy influence on enhancing students' conceptual comprehension of matrix topics in the 11th grade at SMK Raudlatul Uluum Aek Nabara. This is demonstrated by a statistically significant contrast between the experimental and control groups. In particular, the experimental group that engaged with AR resources experienced a rise in the average posttest score from 60.25 (pretest) to 82.40, achieving a Normalized Gain (N-Gain) of 0.56, which is categorized as moderate yet surpasses that of the control group (posttest 75.30; N-Gain 0.41). An independent t-test revealed a computed t-value of 2.75, exceeding the critical t-value of 2.00 at a significance level. level of $\alpha=0.05$ (df=58), thus rejecting the null hypothesis and indicating a statistically and pedagogically significant causal difference.

This improvement was not only evident in aggregate scores but also at the granular level across each level of Bloom's revised cognitive taxonomy, where AR consistently outperformed in facilitating the transition from basic understanding (C1: recall, 20-point increase) to higher levels of analysis and synthesis (C4–C6: a 25–26-point increase versus 15 points in the control group), indicating that interactive 3D AR visualization reduces students' cognitive load regarding abstract matrix concepts such as order, elements, addition operations, scalar multiplication, and applications, thereby supporting the construction of deeper, more enduring, and applicable knowledge in accordance with the principles of Dual Coding theory and constructivist learning.

Data from the student questionnaire responses in the experimental group reinforced the cognitive findings with an average score of 4.25 (85% in the 'very good' category), dominated by indicators of engagement (86%), understanding of the material (87%), interactivity (86%), and satisfaction (86%), which empirically validates the role of AR as a psychological catalyst that enhances intrinsic motivation, transforms the paradigm of passive learning into an immersive multisensory experience, and overcomes the main barriers of traditional mathematics education.

Theoretically, this study enriches the field of digital pedagogy with empirical evidence that AR functions as a transformative medium that bridges the gap between mathematical abstraction and physical reality, as well as providing local contextualisation relevant to Indonesia's Merdeka Belajar Curriculum, where the integration of innovative technology is imperative to achieving the Pancasila Student Profile oriented towards digital literacy.

The practical contributions of this research include recommendations for vocational high school mathematics teachers to adopt AR as an inclusive, differentiated tool, enabling personalized learning for students with a dominant visual-kinesthetic learning style, while for school policymakers in rural areas such as Aek Nabara, these findings serve as the basis for procuring low-cost mobile AR infrastructure (smartphones/tablets) and teacher training, thereby sustainably improving the quality of vocational education . Nevertheless, these conclusions also acknowledge methodological limitations such as a small sample size (n=60) at a single vocational high school location, potential bias in AR implementation fidelity due to variations in students' digital literacy, and a singular focus on the Matrix curriculum, indicating the need for research replication across different educational levels and subjects for broader generalization.

During the implementation of learning using the Assemblr EDU app, several challenges were encountered. Firstly, not all pupils had the same ability to operate the Augmented Reality app, so at the start of the learning process, time was needed to provide an orientation and guidance on using the app. Secondly, the quality of the devices used by pupils varied, meaning that the speed at which three-dimensional (3D) objects loaded and the smoothness of the app's performance were not always consistent. Thirdly, the stability of the internet connection on some occasions affected the process of accessing AR-based materials, particularly when loading learning content.

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