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THE EFFECTIVENESS OF AUGMENTED REALITY TECHNOLOGY IN MATHEMATICS: A CASE STUDY OF SMP AL AZHAR PLUS BOGOR

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Abstract

The field of mathematics education is rapidly advancing, particularly with the introduction of augmented reality (AR) technology as one of the tools used as an innovative learning medium. This research seeks to assess how the incorporation of AR influences students' grasp of mathematical concepts. This study is an experimental quantitative research using the experimental design method, with a population of 37 students from class IX of SMP Al Azhar Plus Bogor. The researcher obtained 30 students as samples based on purposive sampling technique, which were then divided into 2 groups: 15 students as the experimental group and 15 students as the control group. The experimental group underwent mathematics learning utilizing AR technology with 3D teaching materials that were prepared and accessible via smartphones through a barcode, covering topics such as congruent, similar, and spatial figures. Meanwhile, the control group followed conventional teaching methods using books as teaching materials with the same subject coverage. The study's results emphasize the substantial improvement in students' understanding of mathematical concepts through the effective utilization of AR. This improvement encompasses students' abilities to solve mathematical problems, retain conceptual memory, and actively participate in the learning process. Based on the statistical test results conducted, the experimental group obtained an average of 68.4153 or 68%, which falls into the category of moderately effective, while the control group obtained an average of 16.1508 or 16%, classified as ineffective. The Independent Sample Test yielded a Sig. (2-tailed) value of 0.000 < 0.05, indicating a significant difference in effectiveness between the experimental and control groups. Further data analysis indicates that the learning experience through AR not only provides a better understanding but also offers additional motivation to students, thereby increasing their interest in the subject of mathematics. Moreover, the study observes that a well-integrated instructional design within the curriculum, considering the context of AR usage, can contribute significantly to improved learning outcomes. The consequences of these discoveries strengthen the perspective that augmented reality (AR) is not just a successful educational instrument but can also offer a pleasurable learning encounter within the realm of mathematics education. The outcomes of this study play a substantial role in advancing more interactive approaches to teaching mathematics, with a specific emphasis on enhancing students' conceptual understanding. It is hoped that these findings can serve as a foundation for the implementation of AR in educational curricula as a strategic effort to enhance the quality of mathematics education and enrich students' learning experiences.

Keywords: Augmented Reality, Mathematics, Learning Experience

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INTRODUCTION

The introduction contains the research background, The increasingly advancing technology, including in the field of education, marks the progress of a nation. [1] Currently, learning has been extensively integrated with technology. The progress of technology needs to be balanced with the development and advancement of human resources to enable them to use and compete with this technology in the global arena. [1] Human resources can improve alongside the quality of education obtained. [2] Augmented Reality (AR) is an example of technological development that provides several methods to enhance the learning and teaching experiences for both students and teachers. In Indonesia, AR technology has become integral to research and is extensively cultivated in the educational domain. [3]

Technology holds a pivotal position in education, particularly amid the 21st-century

education transformation and the era of Industry 4.0 characterized by diverse digital devices. [4] Learning materials stand out as a vital component in the educational process. [5] Media acts as a bridge between learners and educators, facilitating communication so that learners can understand what educators teach. [6] The learning process must be interactive, and enjoyable, provide space, and stimulate learners to develop creativity and independence in line with their interests and talents. [7] Learning media that follows technological advancements includes innovations such as Augmented Reality (AR) in the realm of learning. The advantage of AR in education lies in its potential to integrate AR technology into the teaching and learning process, [8] providing more engaging learning media. [9]

Participating in learning activities entails the utilization of ICT as a tool to support the learning process. Additionally, ICT assists teachers in various administrative tasks, personnel management, finance, and other functions. [10] AR, with its ability to combine multimedia with the real world using electronic devices, can provide information anytime and anywhere for students, allowing learning to occur differently. [11] With AR technology, all objects using digital devices become visible and tangible, providing a more detailed and profound experience, [12] Improving students' critical thinking, problem-solving abilities, and educational achievements. [13]

The definition related to Augmented Reality is the technique of combining virtual objects or digital information into the real environment. [14] AR can function interactively in real time and seamlessly blend with real-world objects. [15] The integrated utilization of AR in the educational process holds significant potential for yielding diverse advantages. [16] The benefits of Augmented Reality include enhancing understanding of the environment, transforming the virtual and real-world environment into a new form of interface, and serving as a medium to display relevant information and facts. [17] By using Augmented Reality, which is one of the innovations in instructional media, Anticipated to boost students' interest and comprehension, instructional media is recognized as a factor that can captivate attention, stimulate motivation, and engage students in learning activities. [18] AR can also be beneficial in distance learning, providing a more realistic experience while maintaining proximity between materials and instructors.

Augmented Reality (AR) constitutes a multimedia technology that empowers users to seamlessly perceive a virtual world intricately linked or fused with the actual world, facilitating interactions. [19] AR operates through devices that capture the physical environment and transform virtual elements, including objects, animations, text, data, or audio, observed by users through computer screens, smartphones, tablets, glasses, headsets, or presentation systems on other screens. Coordination between the real world and virtual data is achieved through geolocation and integrated sensors (such as accelerometers and gyroscopes) tracking the user's position relative to their environment and adjusting visual output in response to their movements. [20]

Mathematics is crucial for understanding daily life. [21] Many human activities involve mathematics in problem formulation, modeling, and problem-solving. However, mathematics is often perceived as difficult by students, including those at SMP Al Azhar Plus Bogor, where it is considered challenging due to the use of formulas, complex calculations, and other reasons. Mathematics teaching still relies on conventional methods using teaching modules from books, causing students to become bored. In the sub-topic of spatial structures, a mathematics subject, [22] only the chalkboard is typically used to illustrate the structure, making some sides unclear. Using technology as an engaging learning medium is expected to be a solution to enhance the teaching and learning process. [23]

In the study, the researcher prepared teaching materials covering topics on congruent, similar figures, and spatial figures. In the experimental group, the researcher utilized 3D teaching materials created through the Assemblr Edu website, accessible via smartphones using a barcode. The 3D teaching materials are easy for students to use and understand because flat and spatial figures can be viewed from all angles. For example, in the case of a cube, the material includes visualizations of opening and closing movements from the cube's net form to forming a cube, making the shape, sides, diagonals, and angle measures clearly visible and easy to understand.

The purpose of this research is to examine the effectiveness of utilizing AR technology in students' learning in the subject of mathematics, determining whether the use of AR technology makes student learning effective or not. The hope is that with the integration of AR technology into the curriculum, especially in mathematics lessons, will become a new learning

experience for students at SMP Al Azhar Plus Bogor. Because certain topics in mathematics, such as geometry, require more detailed visualizations, with AR technology, students can not only view in 2 dimensions from a book but also perceive in 3 dimensions.

METHOD

The method used in this study is the experimental design method, employed to test the effectiveness of AR usage in mathematics learning regarding the comprehension of mathematical concepts by students at SMP Al Azhar Plus Bogor. The population consists of 37 ninth-grade students at SMP Al Azhar Plus Bogor. Then, using purposive sampling technique, the researcher obtained a sample consisting of 30 ninth-grade students, which was then divided into 2 groups: an experimental group consisting of 15 students and a control group also consisting of 15 students. Data were obtained from pre-tests, post-tests, and n-gain regarding the comprehension of mathematical concepts. The questions given in the pre-test were identical to those in the post-test, consisting of written tests in the form of essays. The test on the understanding of mathematical concepts comprised five essay questions. In both the experimental and control groups, the same assessment instruments and questions are given. Before each learning session, every student receives a pre-test questionnaire that can be completed in writing within a one-hour lesson or 30 minutes. After the lesson concludes, students are given a post-test questionnaire to complete in writing, within the same timeframe as the pre-test. Subsequently, after obtaining data from the pre-test and post-test scores, the difference between the two mean scores of pre-tests, post-tests, and n-gain was tested using the N-Gain Score test. After obtaining the N-Gain Score test results, the analysis was conducted using a design analysis table to identify disparities in the effectiveness of learning using Augmented Reality and conventional learning. Subsequently, an Independent Sample t-test was carried out to ascertain if a notable distinction exists between AR learning and conventional learning, aiming to evaluate the extent of AR learning's impact on students' comprehension of mathematical concepts.

RESULT AND DISCUSSION

Data was collected from two separate groups, and N-Gain Score calculations were performed to establish the average scores for each group. Throughout the study, as illustrated in Table 1, the author employed a distinctive methodology for the experimental group through the integration of Augmented Reality, while the control group either did not receive similar treatment or exclusively followed conventional learning methods. Following the acquisition of data from pretests and posttests, as presented in Table 2 and Table 3, this data underwent analysis through the N-Gain Score test, with a subsequent examination of the mean outcomes for each group.

Table 1. Analysis Design

Group	Pre Test	Treatment	Post Tes
Eksperimental	Y_1	X	Y_2
Control	Y_1		Y_2

Table 2. Experimental Group Data

Subject Number	Group	Pre Test	Post Test
1	1	60	85
2	1	55	90
3	1	60	85

4	1	65	80
5	1	60	85
6	1	50	90
7	1	50	90
8	1	55	85
9	1	60	90
10	1	60	80
11	1	50	85
12	1	65	90
13	1	50	95
14	1	50	80
15	1	60	90

Table 3. Control Group Data

Subject Number	Group	Pre Test	Post Test
1	2	55	65
2	2	50	70
3	2	50	60
4	2	60	70
5	2	60	65
6	2	60	65
7	2	65	60
8	2	65	60
9	2	50	60
10	2	60	65
11	2	50	75
12	2	55	60
13	2	60	70
14	2	50	60
15	2	60	60

Table 4. Results of the N-Gain Score Test Calculation for the Experimental Group

Subject Number	N-Gain Score (%)
1	62.50
2	77.78
3	62.50
4	42.86
5	62.50
6	80.00
7	80.00
8	66.67
9	75.00
10	50.00
11	70.00
12	71.43
13	90.00
14	60.00
15	75.00
Mean	**68.4153**
Minimum	**42.86**
Maximum	**90.00**

Table 5. Results of the N-Gain Score Test Calculation for the Control Group

Subject Number	N-Gain Score (%)
1	22.22
2	40.00
3	20.00
4	25.00
5	12.50
6	12.50
7	-14.29
8	-14.29

9	20.00
10	12.50
11	50.00
12	11.11
13	25.00
14	20.00
15	00.00
Mean	**16.1508**
Minimum	**-14.29**
Maximum	**50.00**

Table 6. Categories of Interpretation for N-Gain Effectiveness

Percentage (%)	Interpretation
< 40	Ineffective
40 – 55	Less Effective
56 – 75	Moderately Effective
>76	Effective

Table 4 displays the results derived from the computation of the N-Gain Score test, indicating that the experimental group achieved an average score of 68.4153, with a minimum of 42.86 and a maximum of 90.00. Meanwhile, Table 5 illustrates the results of the N-Gain Score test calculation, revealing that the experimental group attained an average of 16.1508, with a minimum score of -14.29 and a maximum of 50.00. Upon analyzing the mean results for both the experimental and control groups, as presented in Table 6, it is observable that the experimental group, which employed AR for learning, reached an average of 68.4153 or 68%, indicating a moderately effective level.

In contrast, the control group, employing conventional learning methods, produced an average of 16.1508 or 16%, signifying ineffectiveness. Consequently, based on the N-Gain Score test findings, one can deduce that the application of The implementation of Augmented Reality technology substantially improves students' comprehension of mathematics, while conventional learning proves ineffective in cultivating such comprehension. Subsequently, a t-test for independent samples was carried out to assess the statistical significance of the difference in effectiveness between AR learning and conventional learning.

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Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Kelas	Statistic	df	Sig.	Statistic	df	Sig.
NGain_Persen	Eksperimen	.114	15	.200*	.971	15	.868
	Kontrol	.185	15	.180	.937	15	.342

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Figure 1. Test of Normality

Group Statistics

	Kelas	N	Mean	Std. Deviation	Std. Error Mean
NGain_Persen	Eksperimen	15	68.4153	12.22253	3.15584
	Kontrol	15	16.1508	17.17863	4.43550

Figure 2. Group Statistic

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means	
		F	Sig.	t	df
NGain_Persen	Equal variances assumed	.657	.424	9.601	28
	Equal variances not assumed			9.601	25.283

Figure 3. Independent Samples Test (Levene's Test for Equality of Variances)

Independent Samples Test

		t-test for Equality of Means		
		Sig. (2-tailed)	Mean Difference	Std. Error Difference
NGain_Persen	Equal variances assumed	.000	52.26455	5.44362
	Equal variances not assumed	.000	52.26455	5.44362

Figure 4. Independent Samples Test (t-test for Equality of Means)

Independent Samples Test

		t-test for Equality of Means	
		95% Confidence Interval of the Difference	
		Lower	Upper
NGain_Persen	Equal variances assumed	41.11379	63.41531
	Equal variances not assumed	41.05956	63.46955

Figure 5. Independent Samples Test (t-test for Equality of Means)

Before initiating the independent sample t-test, a preliminary normality test was performed to verify the normal distribution of the utilized data. The outcomes of the normality assessment, illustrated in Figure 1, indicate the significance value (Sig.) for both the experimental and control groups. The data is considered to have a normal distribution since the significance value surpasses 0.05. Next, Figure 2 displays the group statistics related to the experimental group with AR learning, which obtained an average of 68.4153 or 68%, falling into the moderately effective category. For the control group with conventional learning, the average was 16.1508 or 16%, classified as ineffective. Following this, as illustrated in Figure 3, The significance value (Sig.) in Levene's Test for Equality of Variances falls below 0.05, precisely at 0.424. This implies that the variability in N-Gain (%) data is consistent among the experimental group and the control group. Furthermore, based on Figure 4, the significance value (2-tailed) is less than 0.05, specifically 0.000. Therefore, with these results, It can be asserted that a substantial variance in effectiveness exists between the learning methodologies of AR and conventional approaches.

CONCLUSION

Based on the results of the conducted research, it can be concluded that the implementation of augmented reality (AR) technology in mathematics learning at SMP Al Azhar Plus Bogor has successfully contributed to the effectiveness of students' understanding of mathematical concepts. The application of AR in the educational setting has notably contributed to enhancing the quality of learning and enriching

students' learning experiences. This study indicates that the intervention of augmented reality in mathematics learning can create a more interactive and engaging learning environment. Through the use of AR, students can experience mathematical concepts visually and practically. They become more enthusiastic because they are presented with moving visuals, bright colors, and various additional components that make learning math enjoyable and not boring. Students can easily see the presentation from various angles so that the sides, angles, and frameworks of flat and spatial figures can be seen. The use of AR technology also makes students more excited because it is a new experience for them, allowing them to better understand the subject matter. Students become more interactive in the learning process, actively discussing and answering example questions provided by the researcher.

The observed improvement in students' understanding of mathematical concepts can be measured through increased abilities in solving mathematical problems, memory retention of concepts, and active participation in learning activities. In comparison to conventional teaching methods, the use of augmented reality demonstrates more positive and effective outcomes in supporting the mathematics learning process. It is essential to note that the success of implementing augmented reality in mathematics learning is not solely driven by technological aspects but also by careful instructional design and the integration of AR that aligns with the curriculum. Therefore, the findings of this research support the perspective that augmented reality technology has significant potential as an innovative learning tool. It can enhance students' understanding of mathematical concepts and provide a more engaging and satisfying learning experience.

REFERENCES

[1] F. Amalia, R. T. Sulistyo, N. Santoso, and A. Hendra Brata, 'ANALISIS KUALITAS E-LEARNING SEBAGAI MEDIA PEMBELAJARAN DALAM MENINGKATKAN HASIL BELAJAR SISWA SMK'.

[2] A. J. Pratama, D. Irfan, and H. Effendi, 'Studi Literature Penggunaan Media Pembelajaran Menggunakan Teknologi Augmented Reality Pada Sekolah Kejuruan', *JAVIT : Jurnal Vokasi Informatika*, pp. 47–55, Feb. 2023, doi: 10.24036/javit.v3i1.135.

[3] Y. Aprilinda *et al.*, 'Implementasi Augmented Reality untuk Media Pembelajaran Biologi di Sekolah Menengah Pertama', vol. 11.

[4] H. Purwanta, Sutiyah, Herimanto, M. Pelu, Isawati, and D. A. Kurniawan, 'The Information and Communication Technology Literacy Level of Sukoharjo's Senior High School Students', *Jurnal Nasional Pendidikan Teknik Informatika (JANAPATI)*, vol. 12, no. 2, pp. 234–243, Jul. 2023, doi: 10.23887/janapati.v12i2.58554.

[5] A. Tsaaqib, A. Buchori, and D. Endahwuri, 'EFEKTIVITAS PENGGUNAAN MEDIA PEMBELAJARAN VIRTUAL REALITY (VR) PADA MATERI TRIGONOMETRI TERHADAP MOTIVASI DAN HASIL BELAJAR MATEMATIKA SISWA SMA', *Jurnal Ilmiah Pendidikan Matematika*, vol. 7, no. 1.

[6] Siti Nurnaena and S. Gumiandari IAIN Syekh Nurjati Cirebon, 'EFEKTIVITAS PENGGUNAAN AUGMENTED REALITY UNTUK MENINGKATKAN PENGUASAAN KOSA KATA BAHASA ARAB DAN HASIL BELAJAR SISWA DI SEKOLAH MAN 1 CIREBON', 2022.

[7] S. D. Riskiono, T. Susanto, and K. Kristianto, 'Augmented reality sebagai Media Pembelajaran Hewan Purbakala', *Krea-TIF*, vol. 8, no. 1, p. 8, May 2020, doi: 10.32832/kreatif.v8i1.3369.

[8] A. N. Cahyono, Y. L. Sukestiyarno, M. Asikin, Miftahudin, M. G. K. Ahsan, and M. Ludwig, 'Learning mathematical modeling with augmented reality mobile math trails program: How can it work?', *Journal on Mathematics Education*, vol. 11, no. 2, pp. 181–192, May 2020, doi: 10.22342/jme.11.2.10729.181-192.

[9] A. Latifah, R. Setiawan, and A. Muharam, 'Augmented Reality dalam Media Pembelajaran Tata Cara Berwudhu dan Tayamum', *Jurnal Nasional Pendidikan Teknik Informatika (JANAPATI)*, vol. 10, no. 3, p. 167, Dec. 2021, doi: 10.23887/janapati.v10i3.40869.

[10] U. Hanifah, S. & Niar, A. Universitas, and A. Dahlan Yogyakarta, 'PERAN TEKNOLOGI PENDIDIKAN DALAM PEMBELAJARAN', 2021. [Online]. Available: https://ejournal.stitpn.ac.id/index.php/islamika

[11] Q. Jafar Adrian, A. Ambarwari, and M. Lubis, 'PERANCANGAN BUKU ELEKTRONIK PADA PELAJARAN MATEMATIKA BANGUN RUANG SEKOLAH DASAR BERBASIS AUGMENTED REALITY', *Jurnal SIMETRIS*, vol. 11, no. 1, 2020.

[12] P. W. Aditama, C. P. Yanti, I. Gede, I. Sudipa, P. S. Digitalisasi, and B. Bali, 'IMPLEMENTATION OF VIRTUAL REALITY MUSEUM LONTAR PRASI BALI AS A CULTURAL EDUCATION MEDIA', vol. 12, no. 3, 2023, doi: 10.23887/janapati.v12i3.69620.

[13] M. I. S. Guntur, W. Setyaningrum, H. Retnawati, M. Marsigit, N. A. Saragih, and M. K. bin Noordin, 'Developing augmented reality in mathematics learning: The challenges and strategies', *Jurnal Riset Pendidikan Matematika*, vol. 6, no. 2, pp. 211–221, Nov. 2019, doi: 10.21831/jrpm.v6i2.28454.

[14] I. Muhammad, F. Marchy, H. K. Rusyid, and D. Dasari, 'Analisis Bibliometrik: Penelitian Augmented Reality Dalam Pendidikan Matematika', *JIPM (Jurnal Ilmiah Pendidikan Matematika)*, vol. 11, no. 1, p. 141, Sep. 2022, doi: 10.25273/jipm.v11i1.13818.

[15] S. Rizal and Y. Yermiandhoko, 'PENGEMBANGAN MEDIA PEMBELAJARAN MATEMATIKA MATERI JARING-JARING KUBUS DAN BALOK BERBASIS AUGMENTED REALITY PADA KELAS V SEKOLAH DASAR'.

[16] J. Cabero-Almenara and R. Roig-Vila, 'The motivation of technological scenarios in Augmented Reality (AR): Results of different experiments', *Applied Sciences (Switzerland)*, vol. 9, no. 14, Jul. 2019, doi: 10.3390/app9142907.

[17] K. A. Ariningsih, 'AUGMENTED REALITY DALAM MULTIMEDIA PEMBELAJARAN I Nyoman Widhi Adnyana Sekolah Tinggi Ilmu Komputer Indonesia', 2019. [Online]. Available: https://www.researchgate.net/publication/334362261

[18] M. N. Faiza, M. T. Yani, and A. Suprijono, 'Efektivitas Penggunaan Media Pembelajaran IPS Berbasis Augmented Reality untuk Meningkatkan Kompetensi Pengetahuan Siswa', *Jurnal Basicedu*, vol. 6, no. 5, pp. 8686–8694, Jul. 2022, doi: 10.31004/basicedu.v6i5.3901.

[19] H. Prayitno and A. Indah Juwita, 'DIAJAR: Jurnal Pendidikan dan Pembelajaran Efektivitas Aplikasi Media Pembelajaran Berbasis Augmented Reality pada Mata Pelajaran Geografi (Studi Kasus Kelas X IPS SMA Negeri 2 Bungo)', vol. 2, no. 2, pp. 259–266, 2023, doi: 10.54259/diajar.v2i2.1528.

[20] N. Elmqaddem, 'Augmented Reality and Virtual Reality in education. Myth or reality?', *International Journal of Emerging Technologies in Learning*, vol. 14, no. 3, pp. 234–242, 2019, doi: 10.3991/ijet.v14i03.9289.

[21] Yulia, A. Pratiwi, and S. A. Arnomo, 'Sistem Edukasi Pengenalan Rumus Matematika Menggunakan Aughmented Reality Berbasis Android', *Jurnal Sistim Informasi dan Teknologi*, pp. 87–93, Jul. 2022, doi: 10.37034/jsisfotek.v4i2.133.

[22] I. P. Sari, I. H. Batubara, A. H. Hazidar, and M. Basri, 'Pengenalan Bangun Ruang Menggunakan Augmented Reality sebagai Media Pembelajaran', *Hello World Jurnal Ilmu Komputer*, vol. 1, no. 4, pp. 209–215, Dec. 2022, doi: 10.56211/helloworld.v1i4.142.

[23] N. J. Wardhana, I. Ketut, R. Arthana, D. Gede, and H. Divayana, 'PENGEMBANGAN APLIKASI VIRTUAL REALITY 3D PENGENALAN MANUSIA PURBA BANGSA INDONESIA UNTUK SMA KELAS X (STUDI KASUS SMA NEGERI 2 SINGARAJA)'.