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Augmented Reality in Mathematics Education: Evaluation of the Effect of Interactive Books on Student Motivation and Understanding

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***Abstract*— This research evaluates the effectiveness of Augmented Reality-based mathematics books (MathAR Book) in increasing motivation and understanding of mathematics concepts for high school students by comparing them with conventional books. Two classes were randomly selected using an experimental design: one using the MathAR Book and one using a conventional book. The analysis results show that although MathAR Book makes learning more interactive and exciting, there is no significant difference in motivation and understanding of mathematics compared to conventional methods. Student motivation did not increase significantly, and Cohen's d showed a small effect. In-depth interviews and focus group discussions revealed students' enthusiasm for augmented reality (AR) technology and technical barriers such as slow applications and a lack of detailed guidance. Students familiar with technology feel more comfortable, while those less familiar find it difficult. Suggestions for improvement include improving the user interface and better integration with conventional textbooks. Mathew's Book has the potential to improve mathematics learning and student motivation. However, its success depends on adequate technical and pedagogical support and effective integration with traditional learning methods. Further research is needed to overcome these obstacles and optimize the design of the MathAR Book.**

Keywords— ***Augmented Reality (AR); Mathematics Books; Motivation to learn; Understanding Mathematical Concepts; Interactive Learning.***

I. INTRODUCTION

Student motivation is essential in mathematics learning because this subject is often considered complex and abstract [1]. Students motivated to learn mathematics tend to seek a deep learning by asking questions, discussing and looking for solutions [2]. Apart from that, strong motivation also allows students to see the relevance of mathematics in their daily lives, increasing their interest in applying mathematical concepts. However, observation results show the low interest of students in mathematics books in one of the senior high schools in Indonesia, which indicates the need for improvements in the presentation of learning material. Therefore, learning needs to be packaged in an interesting way to motivate students to learn and minimize problems in the learning process [3]. Based on observation results, this is reflected in low interest in learning caused by less attractive mathematics books, lack of student involvement in the learning process, low advances, students' interest in reading mathematics books can significantly impact their understanding of mathematics material and problem-solving ability [4]. This problem becomes increasingly important because mathematics books are often the primary source of information and understanding of mathematical concepts outside the classroom environment. In this way, educators can design learning approaches that are more effective and interesting for students, encouraging their interest in exploring the world of mathematics through reading.

Therefore, changes in learning approaches are needed to overcome these challenges and rebuild students' interest and motivation in studying mathematics, which requires innovative, creative and highly relevant approaches to increase learning effectiveness [5]. In the era of digital technology, learning approaches that integrate advanced technology are becoming increasingly prominent [6], [7] and make a significant contribution to the quality of education [8] as well as optimizing technology to create competitive

advantages [9]. The role of teachers in utilizing technology as a learning medium is vital [10][11]. Teachers must develop content, pedagogy and learning designs integrating technology [12]. One of the advantages of using this technology is its ability to be used as an effective, innovative and educational learning tool [13]. So, there is a need for mathematics learning tools that suit students' needs [14]. Using technology in the learning environment opens opportunities for new learning explorations, allows educators to test innovative learning approaches, and applies new methods that enrich the learning relevance of the material to real life, and lack of support and appreciation.

In an era of technological experience [15]. One technology that attracts attention in the learning context is augmented reality (AR). The purpose of Augmented Reality is to create technology that allows combining computer-generated digital content with natural environments directly and in real-time [16]. The use of Augmented Reality (AR) in an educational context stimulates student participation in Class, increases understanding of subject matter, strengthens spatial understanding abilities, increases long-term memory retention, and stimulates student learning motivation [17] as well as improving the learning experience and helping students improve academic performance [18][19]. Augmented reality technology also significantly increases enjoyment in the learning process [7]. Augmented Reality (AR) has been proven effective as a mathematics learning tool, increasing self-confidence and understanding, strengthening visualization skills, and making learning more interactive at all levels of education [20][21].

So, the author researched the effectiveness of technology-based mathematics books, especially Augmented Reality-based mathematics books. Previous research conducted by [22] shows that interest in reading using Augmented Reality (AR) text is one of the most significant factors in the analysis. This is proven by the results of measurements using the Emotiv Insight device and students' perceptions of these factors. Students are genuinely stimulated when interacting with new technologies, such as AR, applied in traditional text contexts. Regarding the emotional aspect, based on the data collected in the experiment, the integration of enhanced reality in traditional books can increase students' interest in learning. AR-based books provide students with a more interactive experience with learning materials, allowing them to interact directly with mathematical objects in a natural environment [11]. Through this technology, students not only deepen their understanding of mathematical concepts but also feel more involved in the learning process, which can increase their motivation and psychological readiness to face material that may be considered problematic. This research aims to evaluate the effect of Augmented Reality-based mathematics books (MathAR Book) on students' motivation and understanding of mathematical concepts and compare them with conventional methods. This research also tested significant differences in motivation and learning outcomes between groups who used MathAR Book and conventional books and involved in-depth interviews and Focus Group Discussions (FGD) to understand students' perceptions and barriers regarding using MathAR Book.

II. METHOD

This research uses an experimental design with an experimental group and a control group to evaluate the effectiveness of Augmented Reality (AR)-based mathematics books in increasing high school students' motivation. Two classes were randomly selected: one Class of 17 students using AR books as the experimental group and one Class of 18 as the control group using conventional books. Learning material about chance events was given to both groups, with the AR version for the experimental group and the conventional version for the control group. Before learning, initial observations and interviews were conducted to understand students' problems, needs, and expectations regarding mathematics learning. The experimental group used AR books to increase interactivity during the study, while the control group used conventional printed books. Analysis of learning outcomes is based on pretest and posttest scores. At the same time, student motivation is measured through a posttest questionnaire, with indicators that include the desire to succeed, encouragement to learn, hopes for the future, rewards, and a conducive learning environment [23]. For data analysis, SPSS version 25 was used with the Analysis of Covariance (ANCOVA) method to control covariate variables (pretest scores) and measure the impact of treatment (AR book). The results of the motivation questionnaire were analyzed using the Independent T-Test. This research combines quantitative and qualitative approaches with in-depth interviews and focus group discussions (FGD) to explore students' perceptions, barriers and suggestions regarding using the MathAR Book, providing a comprehensive picture of the effects and experiences related to this Book..

III. RESULTS AND DISCUSSION

Results

Analysis of Test Results

TABLE I. TESTS OF NORMALITY

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	*df*	*Say.*	*Statistic*	*df*	*Say.*
Residual for Postest	.123	35	.200*	.957	35	.182

The normality test results using Kolmogorov-Smirnov for the residuals from the posttest showed a statistical value of 0.123 with a significance (Sig.) of 0.200. In the context of the Kolmogorov-Smirnov test, the null hypothesis (H0) states that the residual data is usually distributed. With a significance value greater than 0.05, namely 0.200, we fail to reject the null hypothesis. This means the residual data from the posttest can be considered normally distributed. Therefore, the assumption of normality is met, which makes it possible to continue data analysis, such as ANCOVA, without problems regarding data distribution.

TABLE II. LEVENE'S TEST OF EQUALITY OF ERROR VARIANCES

F	df1	df2	Say.
.158	1	33	.693

Levene's Test of Equality of Error Variances results for the posttest dependent variable show an F statistical value of 0.158 with a significance (Sig.) of 0.693. This test is used to test the homogeneity of error variance between groups. This test's null hypothesis (H0) states that the error variance between groups is the same. Since the significance value is more significant than 0.05, 0.693, we fail to reject the null hypothesis. This means there is no significant difference in error variance between the experimental and control groups. Thus, the assumption of homogeneity of variance is met, which supports the continuation of data analysis such as ANCOVA with the assumption of uniform variance among groups.

TABLE III. ANOVA

	Sum of Squares	df	Mean Square	F	Say.
Between Groups	17.766	1	17.766	.266	.609
Within Groups	2201.556	33	66.714		
Total	2219.322	34			

The results of the Unstandardized Residual analysis show that the significance value (p-value) is 0.609. This value is well above the general significance threshold of 0.05, which means there is no significant difference between the groups tested based on the unstandardized residuals. In other words, the observed differences between the groups are not statistically significant.

Motivational Questionnaire Analysis

This research conducted a t-test for two independent samples to evaluate the effect of using the MathAR Book on student learning motivation. This test compares the average motivation between the experimental group that used MathAR Book and the control group that did not use this treatment.

TABLE IV. INDEPENDENT SAMPLES TEST

	Levene's Test for Equality of Variances		t-test for Equality of Means			
	F	*Say.*	*t*	*df*	*Significance*	
					One-Sided p	*Two-Sided p*
Equal variances assumed	3.530	.069	.507	33	.308	.616
Equal variances are not assumed.			.512	29.84	.306	.612

The table shows the results of the t-test for independent samples. Levene's test shows the Sig value. 0.069, more significant than 0.05, means that the variances of the two groups are considered equal. In the t-test, assuming equal variances, the t-value is 0.507, and the two-sided p-value is 0.616. Assuming unequal variances, the t-value is 0.512, with a two-sided p-value of 0.612. Both p-values were more outstanding than 0.05, indicating no significant difference between the means of the two groups.

TABLE V. LEVENE'S TEST OF EQUALITY OF ERROR VARIANCES

	Standardize	Point Estimate	95% Confidence Interval	
			Lower	Upper
Cohen's d	6.63835	.171	-.494	.834
Hedges' correction	6.79414	.167	-.483	.815
Glass's delta	7.75356	.147	-.520	.809

Cohen's d in the table shows a value of 0.171, with a 95% confidence interval between -0.494 and 0.834. This indicates a small and insignificant effect between the two groups.

Discussion

This research shows that the assumptions of normality and homogeneity of variance have been met, allowing ANCOVA analysis to be carried out without problems. The Kolmogorov-Smirnov and Levene's tests showed that the residual data was normally distributed (Sig. 0.200) and no significant difference in error variance between groups (Sig. 0.693). The pretest results significantly influence the posttest scores, while the differences between classes are insignificant. In addition, t-test analysis shows that using MathAR Book does not significantly increase students' learning motivation compared to the control group, with Cohen's d values showing a minimal and insignificant effect (p-values 0.616 and 0.612). Overall, the MathAR Book does not show a significant increase in learning motivation compared to conventional methods.

The results of in-depth interviews revealed various student perceptions regarding using the MathAR Book in mathematics learning. Most students feel enthusiastic the first time they use MathAR Book because this approach is considered innovative and exciting compared to traditional learning methods. Interactive visual displays create new and fun learning experiences for students. However, some students less familiar with AR technology feel awkward and confused at the beginning of use. Regarding understanding mathematical concepts, some students feel that the MathAR Book helps them understand the material better through more transparent and interactive visualizations. However, some other students felt no significant difference in understanding concepts compared to conventional methods and still relied on textbooks for more detailed explanations. In the technical aspect, some students experienced obstacles such as applications running slowly, difficulty operating AR features, and limitations of the devices used. These findings are reinforced by [24] that the AR application on smartphones cannot directly scan markers, so it takes time to display the image. Students who are more familiar with technology feel more comfortable, while less familiar students feel overwhelmed and need more time to adjust. Students also love the visual and interactive aspects of MathAR Book, which makes learning math more enjoyable. However, there is

criticism regarding the need for more detailed text explanations in the application, so they still have to use conventional textbooks for a more complete understanding.

The focus group discussions (FGD) results showed that the student group considered the MathAR Book an exciting and innovative tool. They agreed that this tool provides a different learning experience than conventional learning methods, although its effectiveness in improving understanding of mathematical concepts varies depending on each student's learning preferences. Some students feel that the interactive and visual approach of MathAR Book increases their motivation to learn, making them more interested and engaged. However, other students felt a slight change in motivation because they still had to learn concepts traditionally. The FGD also revealed the obstacles faced by students, such as initial lack of understanding of AR technology, device limitations, and lack of guidance from teachers in maximizing the use of MathAR Books, which affected the effectiveness of learning and student comfort. As suggestions for improvement, students suggested improving the user interface to make it more intuitive and easier to use, as well as providing better-supporting tools at school. They also proposed integrating the MathAR Book more closely with conventional textbooks to provide a more comprehensive and detailed learning experience.

IV. CONCLUSIONS

The results of in-depth interviews and FGDs show that the MathAR Book has the potential to improve mathematics learning through interesting and interactive visualizations. However, success is highly dependent on students' technical readiness, comfort in using technology, and adequate learning support. Implications for mathematics learning practice include the need for more systematic integration of technology in the curriculum, training for teachers to optimize the use of MathAR Books, and the provision of adequate infrastructure so that access to this technology is equitable. In addition, a more student-centered learning approach with the use of interactive technology can increase student engagement and facilitate a deeper understanding of mathematical concepts. Further research is recommended to find ways to improve the design and integration of MathAR Books with other learning methods and overcome the technical and psychological barriers students face. Thus, MathAR Books can be optimized to significantly increase student motivation and understanding.

REFERENCES

[1] N. N. N. Maed-Math and L. Tandog Orilla, “The Mediating Effect of Tutorial Videos in Mathematics on the Relationship between Teaching Strategies and Academic Motivation of Students,” Int. J. Humanit. Soc. Sci. Educ., vol. 8, no. 10, pp. 168–193, 2023, doi: 10.20431/2349-0381.0810016.

[2] A. A. Asanre, “Motivational factors as determinant of mathematics achievement of students in senior secondary schools,” Interdiscip. J. Educ. Res., vol. 6, pp. 1–9, 2024, doi: 10.38140/ijer-2024.vol6.19.

[3] L. Laelasari, R. Arfiyanti, M. Nuryanti, S. A. Widodo, and T. A. Arigiyati, “Camtasia Studio Learning Video For Mathematical Literature Levels Students,” 2019, doi: 10.4108/eai.21-9-2018.2281180.

[4] D. S. Nahdi, U. Cahyaningsih, M. G. Jatisunda, and A. Rasyid, “Mathematics Interest and Reading Comprehension as Correlates of Elementary Students’ Mathematics Problem-Solving Skills,” Edukasiana J. Inov. Pendidik., vol. 3, no. 1, pp. 115–127, 2023, doi: 10.56916/ejip.v3i1.510.

[5] N. Imama, S. Utaminingsih, and A. H. Madjdi, “The Effectiveness of the Development of Problem Based Learning Model Based on Bakiak Game Technology in Mathematics Learning in Elementary Schools,” J. Phys. Conf. Ser., vol. 1823, no. 1, pp. 0–10, 2021, doi: 10.1088/1742-6596/1823/1/012079.

[6] H. Elmunsyah, “Interactive learning media innovation: Utilization of augmented reality and pop-up book to improve user’s learning autonomy,” 2019. doi: 10.1088/1742-6596/1193/1/012031.

[7] S. A. Elsayed and H. I. Al-Najrani, “Effectiveness of the Augmented Reality on Improving the Visual Thinking in Mathematics and Academic Motivation for Middle School Students,” Eurasia J. Math. Sci. Technol. Educ., vol. 17, no. 8, pp. 1–16, 2021, doi: 10.29333/ejmste/11069.

[8] M. Crew, T. M. Siregar, A. Ritonga, J. Darma, and F. R. Dongoran, “The Development of Digital Books Aided Augmented Reality (AR) to Improve Self Efficacy in Favor of Distance Learning,” J. Educ. Heal. Sport, vol. 12, no. 9, pp. 61–67, 2022, doi: 10.12775/jehs.2022.12.09.008.

[9] N. Aminah, “A Teaching Practice Design Based on a Computational Thinking Approach for Prospective Math Teachers Using Ed-Tech Apps,” Int. J. Interact. Mob. Technol., vol. 16, no. 14, pp. 43–62, 2022, doi: 10.3991/ijim.v16i14.30463.

[10] S. A. Pramuditya, M. S. Noto, and R. N. Azhar, “Mathematics Media Instruction-Based Android for X-Grade Senior High School,” J. Educ. Expert., vol. 1, no. 1, p. 1, 2018, doi: 10.30740/jee.v1i1p1-10.

[11] S. Suherman, A. Zafirah, F. A. Agusti, and R. Usman, “The Effectiveness of AR-Geometry Interactive Book in Increasing Students’ Mathematical Reasoning Skill,” J. Phys. Conf. Ser., vol. 1554, no. 1, 2020, doi: 10.1088/1742-6596/1554/1/012075.

[12] M. B. Nadzeri, M. Musa, C. C. Meng, and I. M. Ismail, “Teachers’ Perspectives on the Development of Augmented Reality Application in Geometry Topic for Elementary School,” Int. J. Interact. Mob. Technol., vol. 17, no. 15, pp. 38–52, 2023, doi: 10.3991/ijim.v17i15.40097.

[13] A. Buchori, D. Prasetyowati, and Wijayanto, “Developing Magic Book Math Media Based on Augmented Reality: Expert Validity Analysis,” vol. 417, no. Icesre 2019, pp. 194–199, 2020, doi: 10.2991/assehr.k.200318.038.

[14] A. Hasanah, Y. S. Kusumah, and K. Rahmi, “Rounding-augmented reality book and smartphone for deaf students in achieving basic competence,” J. Phys. Conf. Ser., vol. 1521, no. 3, 2020, doi: 10.1088/1742-6596/1521/3/032064.

[15] S. Poçan, B. Altay, and C. Yaşaroğlu, “The Effects of Mobile Technology on Learning Performance and Motivation in Mathematics Education,” Educ. Inf. Technol., vol. 28, no. 1, pp. 683–712, Dec. 2022, doi: 10.1007/s10639-022-11166-6.

[16] A. Buchori, D. Prasetyowati, and W. Wijayanto, “The effectiveness of using magic book Math in Mathematics learning during the Covid-19 pandemic in Senior High School,” J. Phys. Conf. Ser., vol. 1869, no. 1, 2021, doi: 10.1088/1742-6596/1869/1/012114.

[17] A. Y. N. M. Nadzri, A. F. M. Ayub, and N. N. Zulkifli, “The Effect of Using Augmented Reality Module in Learning Geometry on Mathematics Performance among Primary Students,” Int. J. Inf. Educ. Technol., vol. 13, no. 9, pp. 1478–1486, 2023, doi: 10.18178/ijiet.2023.13.9.1952.

[18] A. Ntagiantas, “An Augmented Reality Children’s Book Edutainment through Participatory Content Creation and Promotion Based on the Pastoral Life of Psiloritis,” Appl. Sci., vol. 12, no. 3, 2022, doi: 10.3390/app12031339.

[19] R. Z. Ramli, “Microorganisms: Integrating Augmented Reality and Gamification in a Learning Tool,” Int. J. Adv. Comput. Sci. Appl., vol. 12, no. 6, pp. 354–359, 2021, doi: 10.14569/IJACSA.2021.0120639.

[20] N. Aziz, S. Z. Ahmad, S. Binsaleh, and W. W. R. Z. W. A. Rahman, “Heuristic Evaluation on Affective 4-Dimensional Augmented Reality Mathematics for Children with Low Vision,” Int. J. Inf. Educ. Technol., vol. 13, no. 2, pp. 313–319, 2023, doi: 10.18178/ijiet.2023.13.2.1809.

[21] J. Wong, “AUGMENTED REALITY FOR LEARNING MATHEMATICS: A PILOT STUDY WITH WEBXR AS AN ACCESSIBLE TOOL,” 2022. doi: 10.5821/conference-9788412322262.1216.

[22] M. Rojas-Contreras, “Measurement of emotional variables through a brain-computer interface in the interaction with books with augmented reality in higher education,” 2020. doi: 10.1088/1742-6596/1674/1/012016.

[23] S. Lestari, S. Syahrilfuddin, N. Hermita, and Z. H. Putra, “The Effect of Realistic Mathematic Approach on Students’ Learning Motivation,” J. Teach. Learn. Elem. Educ., vol. 2, no. 2, p. 145, 2019, doi: 10.33578/jtlee.v2i2.7335.

[24] Permatasari, “TEACHERS’ CHALLENGES IN TEACHING GEOMETRY USING AUGMENTED REALITY LEARNING MEDIA,” AKSIOMA J. Progr. Stud. Pendidik. Mat., vol. 10, no. 4, pp. 2159–2169, 2021, [Online]. Available: https://doi.org/10.24127/ajpm.v10i4.3889.