

MathAR Book Technology Innovation: Effectiveness of Using Augmented Reality-Based Mathematics Books on Students' Mathematical Understanding Ability

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Abstract. Educational innovation continues to develop with advances in digital technology, including the use of Augmented Reality (AR) in learning. This research aims to measure the effectiveness of AR-based mathematics books (MathAR Book) on students' mathematical understanding. MathAR Book integrates traditional learning content with AR elements such as 3D visualization and interactive animations to increase student interest and engagement in learning mathematics. This research methodology uses a quasi-experimental approach with a pretest-posttest design. The sample consisted of class XII students who were randomly selected and divided into an experimental group that used the MathAR Book and a control group that used conventional textbooks. The instruments used include tests of understanding mathematical concepts, learning motivation questionnaires, and in-depth interviews. The results showed a significant increase in students' mathematical understanding in the experimental group compared to the control group. MathAR Book students also showed increased learning motivation and concept visualization abilities. Student feedback indicates that AR creates a more engaging and effective learning environment. In conclusion, the MathAR Book effectively improves students' mathematical understanding.

Keywords: Augmented Reality, MathAR Book, Mathematical Understanding, Educational Technology, Learning Motivation

I. INTRODUCTION

Students' mathematical understanding includes understanding mathematical concepts, procedures and applications in various contexts. However, several problems in the classroom often hinder this increase in understanding. Based on the results of interviews with Al Islam Boarding School high school students in Cirebon, one of the main problems is the student's lack of interest in mathematics books. Many students find mathematics books less exciting and challenging to understand, so they tend to ignore or avoid studying from these books. A teaching approach focusing too much on lectures and routine exercises without actively involving students can make them less interested and not understand the material well. Not all students have adequate access to technology and educational resources that can support more interactive and contextual mathematics learning. The urgency to improve students' mathematical understanding is very high, considering that mathematics is the basis of many scientific disciplines and skills needed in the world of work. In an era of rapid information and communication technology advances, students' mathematical understanding has become one of the main focuses in education that continues to transform. The importance of learning technology in mathematics education is increasing with new opportunities for all students, both at school and at home [1], [2]. Technology offers opportunities and challenges for educational practitioners to integrate it into the world of education [3]. With technology's rapid development, technology integration in education has been widely implemented in classroom teaching [4]. Tools and media for learning mathematics continue to develop over time [5]. Mathematics learning must be active and dynamic constructively to build knowledge from personal experience and interactions with others [6]. Today's mathematics learning must be innovative, creative and meaningful [7]. These innovative learning environments create ubiquitous space and time dedicated to teaching [8].

One exciting innovation in this context is using Augmented Reality (AR) in mathematics learning. AR-based media reflects the learning style of digital native generation students, who are accustomed to digital devices and easily accept learning models integrated with ICT [9]. This technology combines Reality with virtual Reality in specific educational contexts through unique methods and techniques [10]. Recent research reveals that Augmented Reality (AR) increases student engagement, motivation, and knowledge retention [11]. Based on the problems in the classroom, the author created a mathematics book based on Augmented Reality (MathAR Book) to be the focus of exploration in this research

and to measure the effectiveness of its use in the learning context. Augmented Reality adds digital elements to the real world, using mobile technology that supports the creation of new interactive and engaging environments [12], which can positively contribute to various learning styles in mathematics [13]. In this scientific article, we will present the results of exploring how MathAR Book can increase students' understanding, motivation and participation in mathematics learning. Previous researchers showed that books integrating AR technology in learning could turn printed books into interactive ones [12], help students visualize concepts [14], increase user learning autonomy [9], motivate students [15], increasing their engagement [16], and facilitating understanding of concepts [17]. However, research detailing the application of AR in mathematics books is still limited, so this scientific article aims to fill this knowledge gap.

II. METHODS

This research uses a quasi-experimental method where subjects are not randomly grouped but accepted according to actual conditions. This research was carried out by applying the MathAR Book to the Probability of Events material. The learning process was carried out in class XII and involved 17 students in that class. The research design used in this research is a one-group pretest-posttest design, namely, comparing pretest and posttest scores. In this method, before the observer provides treatment, students are first given a pretest (preliminary test), and at the end of learning, students are given a posttest (final test). The data collection instruments used in this research were student interest questionnaires and mathematics understanding tests. At the implementation stage, experimental treatment was given by applying the MathAR Book to see the extent of students' understanding of the application of teaching materials, which was measured by calculating the improvement that occurred before and after learning using the N-Gain (normalized gain) index formula [18]. The N-Gain test is used to calculate the increase in learning outcomes with the formula:

$$N - Gain = \frac{\text{Shoes Postest} - \text{Shoes Pretest}}{\text{Shoes Maximal} - \text{Shoes Pretest}}$$

The following are the N-gain value criteria:

TABLE I
 N-GAIN VALUE CRITERIA.

N-gain value	Criteria
N-gain ≥ 0,70	Height
0,30 < N-gain < 0,70	Currently
N-gain ≤ 0,30	Low

The student interest questionnaire measures students' interest in learning using the MathAR Book media. Positive statements in the strongly agree category receive the highest score, while negative statements in the strongly disagree category receive the lowest score.

The following is the formula used by researchers [18]:

$$P = \frac{f}{N} \times 100\%$$

Where:

P = Percentage of answers

f = Frequency of answers

N = Maximum number of scores

The interest score percentage and criteria are as follows:

TABLE 2
 CRITERIA FOR STUDENT INTEREST

Interest Score Percentage	Criteria
76% - 100%	Height
56% - 75%	Currently
0% - 55%	Low

III. RESULTS AND DISCUSSION

1. MathAR Book implementation

MathAR Book or a mathematics book based on Augmented Reality (AR) about Event Probability material developed in the previous stage using 4D learning design (Define, Design, Develop and Disseminate). Media experts, material experts and practitioners assessed the validity of the MathAR Book. Based on the average assessment results, this MathAR Book has a validity level of 85.98% and is included in the eligible category. This shows that the MathAR Book is suitable for classroom learning and can be applied at the implementation stage without requiring further improvements.



Fig1. MathAR Book design



Fig 2. Implementation of MathAR Book for Students

This implementation stage involves delivering learning material in the classroom at the beginning of learning. Before starting the teaching and learning process, researchers prepared various things such as the syllabus, lesson plans, and MathAR Book as sources for teaching and learning activities. The learning process was carried out in class XII, which involved 17 students. This stage lasts for two meetings in class, each meeting lasting 90 minutes (2 class hours). Before taking part in the lesson, students are given an initial test to measure their abilities. After going through the learning process using the MathAR Book, students are given a posttest to measure their final abilities. Apart from that, students also fill out a questionnaire to assess their interest in the learning that has been carried out. These tests and questionnaires are used to evaluate the effectiveness of the MathAR Book, which researchers have developed.

2. Increasing Students' Comprehension Ability

The increase in students' mathematical understanding is measured based on the results of the pretest and posttest scores. An explanation of students' initial skills is shown in Table 3 below.

TABLE 3
 DESCRIPTIVE STATISTICS OF STUDENTS' INITIAL TEST SCORES (PRETEST)

Shoes Ideal	X Min	XMax	Average	Std. Deviation
100	15	30	20,29	5,99

Based on the results of the pretest carried out on students, it can be seen that the average student score is 20.29, with a standard deviation of 5.99. This indicates that most students scored below the ideal score of 100. Significant variation exists between the minimum score of 15 and the maximum score of 30. Challenges exist in questions involving probability of occurrence, where some students still get low scores. This indicates the need for further efforts to support the understanding and application of these mathematical concepts in order to improve student achievement in subsequent evaluations.

TABLE 4
 DESCRIPTIVE STATISTICS OF STUDENTS' FINAL TEST SCORES (POSTTEST)

Shoes Ideal	X Min	XMax	Average	Std. Deviation
100	70	95	81,18	9,11

Based on the results of the posttest, it can be seen that the average student score reached 81.18 with a standard deviation of 9.11. These results show an improvement from the previous pretest score, reflecting significant progress in students' understanding of the material tested. The score range between 70 and 95 shows that most students can approach or even achieve the maximum expected score. However, the relatively high standard deviation indicates variation in student achievement, indicating that some students may still need additional help to reach the desired level of understanding. These results provide a positive view of the learning methods' effectiveness. They also remind us of the importance of encouraging and supporting students in overcoming the challenges they may face in understanding complex concepts.

TABLE 4
 N-GAIN TEST RESULTS

N-Gain	Max	Min
77	63	94

The results of the N-Gain test show that the increase in students' understanding after the learning process ranges between a minimum score of 63 and a maximum score of 94, with an average N-Gain value of 77. This indicates a significant increase in students' understanding after implementing specific learning methods. A minimum score of 63 indicates that some students have experienced a moderate increase in understanding. In contrast, a maximum score of 94 indicates that some students have experienced a very high increase in understanding. The average N-Gain of 77 reflects that most students experienced an excellent improvement in understanding the material taught, indicating the effectiveness of the learning methods applied. This range of scores also indicates variations in the level of improvement in students' understanding, which individual differences in learning ability and speed of adaptation to new learning methods may cause.

3. Results of Responses to Student Interest in Learning with MathAR Book

Students responded to using the MathAR Book by filling out a questionnaire provided by the researcher. This questionnaire was given to students after they had finished using the MathAR Book. The aim was to enable researchers to evaluate how effective Augmented Reality (AR)--based mathematics books were in supporting student learning. The results of the analysis of student responses to each question are presented in Table 5 below.

TABLE 5
 RESULTS OF STUDENT INTEREST RESPONSES

No	Criteria	Score
1.	<i>MathAR Book</i> This is very practical and flexible, making it easier to learn	83,82
2.	<i>MathAR Book</i> still lacks so much that I do not want to use it	82,35
3.	The material presented in <i>the MathAR Book</i> is explicit and does not cause material misunderstandings for me	82,35
4.	I feel lazy studying with <i>MathAR Book</i> . This	80,88
5.	I can effectively understand the concept of geometric transformation material using <i>the MathAR Book</i> . This	82,35
6.	I feel uncomfortable using <i>the MathAR Book</i> . This	83,82
7.	I am having trouble learning to use it. <i>MathAR Book</i> This	80,88
8.	<i>MathAR Book</i> has a pleasant appearance, so it is interesting to learn	85,29
9.	The material contained within <i>MathAR Book</i> This is presented so complicated	80,88
10.	Using <i>MathAR Book</i> as a learning medium encourages me to study harder	82,35
11.	Using <i>MathAR Book</i> makes me increasingly confused about understanding the material of opportunity events	83,82
12.	Overall, I am satisfied with <i>the MathAR Book</i> . This	80,88

Based on the calculations above, the average Percentage of students eligible to use the MathAR Book is 82.88%. After being converted into a scale conversion table, the MathAR Book is 76%—100%. Thus, it can be concluded that the MathAR Book is assessed with high criteria.

IV. CONCLUSIONS

The MathAR Book, developed by researchers, increased students' mathematical understanding of the Probability of Events. Increasing students' mathematical understanding abilities using MathAR Book was recorded as having a high-quality increase. The MathAR Book learning media provides significant benefits by improving the quality of student learning outcomes and growing their interest in learning mathematics. An increase in students' interest in learning MathAR Book can be observed from their active participation in interactive activities in class. This learning method is

considered refreshing for students, making them more active and enthusiastic. They tend to feel curious and do not feel bored during the learning process.

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