Development of Augmented *Reality-Based Applications* for Personalization of Elementary School Mathematics Learning

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Abstract. This research aims to develop a valid and effective MathFlex learning application. This application offers personalized AR-based mathematics learning and responds to the diversity of student learning styles. This research uses the ADDIE model which consists of five stages and the study subjects were 25 students. Data analysis uses qualitative and quantitative techniques through surveys, observation, interviews, and tests. The research results showed that material experts gave a feasibility percentage of 88.5%, design experts 87.5%, and student responses were 87.5% in trial I and 90.42% in trial II. This AR application is very good and worthy of use. The average score before using the application was 62, and after using the application reached 90 with an N-gain score of 0.73. Student response questionnaires about the effectiveness of the application reached 88%. AR applications are effective for elementary school mathematics learning with the assumption that mathematics scores increase when using Augmented Reality-based applications.

Keywords: Development, Augmented reality, Personalized Learning, Mathematics

1 Introduction

Mathematics learning is one of the important subjects for students to master. Mathematics is the basis of various other sciences. Therefore, it is important for students to have a strong understanding of mathematics. The curriculum implemented in Indonesia mandates that mathematics learning in elementary schools must be oriented towards *higher order thinking skills*. This high-level thinking ability can be trained through learning that uses digital technology, one of which is *Augmented reality* (Istiah et al, 2023). [5]

In higher education, the Elementary Mathematics Learning course is included in the group of Expertise Courses (MKBK) with a weight of 3 credits. This course is a course that must be taken by prospective teacher students. This course discusses various aspects related to

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mathematics learning in elementary school, ranging from mathematics learning theories, mathematics learning materials, mathematics learning strategies, and mathematics learning evaluations

Based on the results of observations on field conditions in mathematics courses taught in the PGSD Study Program, it is clear that there are large variations in students' learning styles, levels of understanding of mathematical concepts, and interest in learning. Each student has unique learning preferences, ranging from visual, auditory, to kinesthetic learning styles. Observations also show that this diversity can create gaps in concept understanding and learning motivation among students.

Learning personalization is an approach in the world of education that emphasizes tailoring the learning experience to meet the unique needs, preferences, and abilities of each individual student. The concept of personalized learning recognizes that each student has a different learning style, speed of understanding, and interests (Nesbit et al., 2020). [9] The importance of personalizing learning is becoming increasingly felt in this context. As expressed by Gardner (2006), when teaching is adapted to the learning style of students, learning will become more effective and trigger a deeper understanding. [4]

The application of AR technology in mathematics learning not only creates an interactive and contextual learning experience, but can also be adapted to the learning style of students. Adjusting the curriculum and learning methods to accommodate the individual needs of students is crucial to achieve optimal learning outcomes. However, this challenge is reinforced by the limited resources and time that teachers have in elementary school. This is the background to the need for innovative approaches such as *Augmented reality* (AR) that can help create learning experiences that are tailored to the characteristics of each student.

Augmented reality (AR) is a technology that combines elements of the real world with digital elements, resulting in an experience that combines the physical and virtual worlds. This technology can be used to view virtual objects in the real world in real time. The virtual object can be an image, video or animation. Milgram and Kishino (1994) stated that AR is on a spectrum between the virtual world and the real world, with the aim of improving human interaction with its environment. [8]

The use of digital technology, especially *Augmented reality* (AR), in mathematics learning has received significant attention from academics and education practitioners. According to Johnson and Johnson (2016), the use of *augmented reality* in math learning opens up new opportunities to deepen conceptual understanding and increase student engagement through 3D visualizations that provide clearer and more concrete images. 6] This is in line with the findings of research by Li et al. (2018) which stated that AR not only facilitates the understanding of mathematical concepts, but also encourages students' creativity and exploration in facing problem-solving challenges. [7]

Support for the benefits of using AR technology in mathematics learning is also found in a study by Wang et al. (2020) which states that mathematics learning by utilizing *Augmented reality* encourages students to be actively engaged, increase learning motivation, and provide a more interactive learning experience. [10] These findings reinforce the view that the integration of AR technology not only supports the aspect of understanding mathematical concepts, but also has a positive impact on the aspects of motivation and involvement of students in the learning process.

These studies show that learning mathematics with digital technology, especially *augmented reality*, can provide benefits for students, including increasing students' understanding of mathematics materials, increasing students' motivation to learn, reducing learning gaps, developing higher-level thinking skills, and making mathematics learning more interactive, interesting, and meaningful.

This context provides an important foundation for the development of *Augmented reality* (AR)-based applications for the personalization of elementary mathematics learning. This application is named MathFlex. MathFlex will provide personalized math teaching materials based on students' learning styles. By utilizing visual, auditory, and kinesthetic elements, MathFlex is able to provide more meaningful and relevant learning for each learner.

In this context, MathFlex is not only a solution to improve digital literacy and mathematical understanding, but also to support individual differences in learning styles, making mathematics learning more inclusive and useful for all students at the elementary school level. Moreover, this research not only meets the demands of a curriculum that focuses on responsive learning, but also makes a significant theoretical contribution. The integration of technology in mathematics learning, as embodied in MathFlex, is expected to enrich the learning experience of students and form a critical digital literacy foundation in dealing with information complexity in this digital era.

2 Method

This research approach uses the ADDIE model (Analysis, Design, Development, Implementation, Evaluation). According to Borg and Gall (2003), the research and development approach is a procedure used to develop and validate a product or process, and within it there are steps in the development cycle. [3]

Fig. 1. Reserach Design.

The following is a brief explanation for each stage of the development procedure: (1) Analysis Stage: this stage aims to understand the needs of mathematics learning in elementary schools (SD). An in-depth analysis of the curriculum and mathematics learning standards was carried out, as well as mapping the learning styles of students. (2) Design Stage: This stage focuses on designing AR apps and personalized content. Using the findings from the analysis stage, a user-friendly and intuitive interface was designed. (3) Development Stage: the development stage focuses on implementing the designed design into a ready-to-use AR application. The development of AR applications is carried out based on the prototypes that have been made. (4) Implementation Stage: this stage marks the application of AR applications in the classroom mathematics learning environment. AR applications are applied in a number of classrooms that are the location of the research. The users receive intensive training on the use of the app and its integration in daily learning. (5) Evaluation Stage, this stage aims to evaluate the effectiveness of AR applications and their impact on mathematics learning. This stage creates a comprehensive understanding of the extent to which AR applications have successfully met the established mathematics learning objectives, as well as provides a foundation for further refinement and development.

The researcher used quantitative descriptive data analysis using the following formula:

$$Ps = \frac{\sum n}{Maximum} \times 100\%$$

Source: Suharsimi Arikunto, 2014 [2]

Information:
Ps : Score percentage
Σn : The number of scores obtained

The results of the data score percentage are changed based on the score criteria by applying the following formula:

Table 1. Eligibility Criteria

Percentage	Criterion
82% - 100%	Highly Worthy
63% - 82%	Proper
44% - 62%	Quite Decent
25%- 43%	Less Worthy

Source: Suharsimi Arikunto, 2014 [2]

Based on the table above, if the validation results are in the percentage range of 63% - 100%, then Augmented reality-based applications are feasible or very feasible for personalizing elementary school mathematics learning.
And for the effectiveness analysis is carried out using the *N – Gain Score calculation method* is with the following formula:

$$N - Gain = \frac{Posttest\ Score - Pretest\ Score}{Maximum\ Score - Pretest\ Score}$$

Source: Meltzer in Aprianti, 2020 [1]

Then to find out the interpretation of *N – Gain* can be seen in the table below:

Table 2. CriteriaInterpretation *N – Gain*

Category	Percentage
Tall	$0.70 < GS \leq 1.00$
Keep	$0.30 < GS \leq 0.70$
Low	$0.00 < GS \leq 0.30$

Source: Meltzer in Aprianti, 2020 [1]

Based on the table above, it can be concluded that if the Gain Score obtained is 0.73, the Gain Score in large-scale testing is classified as high

3 Results and Discussion

3.1 Validity

To determine the feasibility of an Augmented reality-based application for personalizing elementary school mathematics learning, a validity test was conducted by experts in materials, design, and language, who assessed specific indicators on the validation sheet. The validation of the learning media was carried out via a quantitative descriptive questionnaire, with results expressed using score distributions and rating scale categories.

Theoretical validity was conducted during the validation test stage by experts in material, design, and language, based on their expertise and logical considerations. The Augmented Reality-based application, developed to personalize elementary school mathematics learning, underwent validation in these three areas to determine its suitability for educational use. The researcher presented the initial design of the application to the experts and provided a validation sheet for assessment. The experts evaluated the application according to the indicators on the sheet, and their assessments were used to determine the theoretical validity of the product.Data from the validation evaluation results of product material experts, product design experts and language experts are as follows:

a. Validation Results Data of Teaching Material Experts

Validation of Augmented Reality-based applications for personalizing elementary school mathematics learning was carried out by Mr. Mulyono, a lecturer at the Postgraduate Program at Medan State University. This assessment aims to collect information to improve and refine the quality of the application. The validation results, including assessment scores related to elementary school mathematics learning, are presented in the following table:

Table 3. The results of the assessment of AR applications by learning material experts

It	Assessment Aspects	Score Percentage
1	Material Suitability	91,6%
2	Material Accuracy	87,5%
3	Updating Materials	87,5%
4	Encourage Curiosity	87,5%
	Percentage T□ Score	**88.5% (Very Decent)**

Based on the table above, the overall learning material expert assessment reached 88.5%, where this range falls into the "Very Appropriate" category. The conclusion from the assessment, comments and suggestions from learning material experts is that an Augmented reality-based application for personalizing elementary school mathematics learning is very worthy of being tried out in the field.

b. Validation Results Data of Learning Design Experts

Validation of learning design experts for Augmented reality-based applications for personalizing elementary school mathematics learning was carried out by Prof. Dr. R. Mursid, S.T., M.Pd., lecturer at the Postgraduate Program at Medan State University. This evaluation covers aspects such as the attractiveness of the physical appearance, the appropriateness of the design usage, the suitability of the format, the alignment of the presentation with the target audience, the clarity of the application, the clarity of the material presentation, and the alignment of the assessment with the materials, as shown in table 3 below:

Table 4. Assessment results of AR-based applications by learning design experts

It	Assessment Aspects	Score Percentage
1	Clarity of goals (indicators) to be achieved	75 %
2	Completeness of information	87,5%
3	Serving order	100 %
4	The Appeal of AR Applications	87,5%
5	Interaction (Stimulus and response)	87,5%
	Percentage T□ Score	**87.5% (Very Decent)**

Based on the results of the assessment by learning design experts which include aspects of clarity of goals (indicators) to be achieved, completeness of information, presentation order, attractiveness of AR applications and interaction (stimulus and response) the achievement rate is 87.5% where the range is at the achievement level of 82% - 100% categorized as "Very Feasible". The conclusion from the assessments, comments and suggestions by learning design experts is that Augmented reality-based applications for personalization of elementary school math learning are well worth a try.

Linguist Validation Results Data

Validation of linguists on the development of augmented reality-based applications for personalization of elementary school mathematics learning by Dr. Baharuddin, ST., M.Pd and Mr. Dr. Wisman Hadi, S.Pd., M.Hum who are lecturers at the Postgraduate Program at Medan State University. Based on assessment tools that have been given to linguists, the quality of augmented reality-based application development for personalization of elementary school mathematics learning for linguists can be seen in the following table:

Table 5. Assessment results of AR-Based Applications by Linguists

It	Assessment Aspects	Score Percentage
1	Businesslike	100 %
2	Communicative	75 %
3	Dialogical and Interactive	75 %
4	Suitability with student development	87,5%
5	Conformity with Language Rules	100 %
	Percentage T□ Score	**87.5% (Very Decent)**

From the table above, it can be concluded that the assessment results by language design experts covering aspects of word usage or language usage in making applications obtained an assessment of 87.5% with the category "Very Eligible".

Based on the validation results above, both the design, language and materials contained in the development of Augmented reality-based applications to personalize elementary school mathematics learning have obtained very good marks so they are worth testing. Summary of assessment results: material validity experts obtained a feasibility percentage of 88.5%, design experts obtained a feasibility percentage of 87.5%, and language experts obtained a feasibility percentage of 87.5%. In the first trial (individual), 25 students' responses regarding feasibility obtained a percentage of 81.92%, including in the "Very Good" category. And in trial II (small group) the response of 25 students regarding feasibility obtained a percentage of 90.42% stated in the category "Very Good".

3.2 Effectiveness

To measure the effectiveness of the Augmented reality-based application for personalization of elementary school mathematics learning, it was measured using the analysis of 1) learning success or learning completeness, 2) student response, the effectiveness of AR application development was achieved if it met two indicators.

Classical learning completeness

Student learning completeness can be calculated by the following formula:

$$\text{PKK} = \frac{\textit{Number of Successfull Students}}{\textit{Total Number of Subject}}\, x \text{ } 100\%$$

$$\text{PKK} = \text{x } \frac{23}{25} 100\%$$

PKK = 96%

Based on the classical learning mastery data above, 96% of individuals have achieved KB ≥ 70%. After the classical learning mastery analysis was conducted, the pre-test and post-test results were calculated using Gain Score. To measure the increase in score and effectiveness of the AR application being developed, a normalized Gain Score formula is applied to compare the results before and after its use.

Table 6. Pre test *and* Post test *results*

Pre test			**Post test**			**Ket**
Value (X)	**Frequency (F)**	**X*F**	**Value (X)**	**Frequency (F)**	**X*F**	
45	1	45	65	1	65	BT
50	2	100	70	2	140	T
55	8	440	75	1	75	T
60	3	180	80	1	80	T
65	1	65	85	1	85	T
70	7	490	90	1	90	T
75	2	150	95	17	1615	T
80	1	80	100	1	100	T

Sum	**1550**	**Sum**	**2250**
Average	**62**	**Average**	**90**
Standard Deviation	**12.2**	**Standard Deviation**	**12.2**

Then it is hit with the following formula N – Gain Score:

$$g = \frac{Posttest\ Score - Pretest\ Score}{Maximum\ Score - Pretest\ Score}$$

$$g = \frac{90-62}{100-62}$$

$$g = 0.73$$

Based on the completion results, the average value of classical learning completion reached 90, indicating that KB ≥ 96% had been achieved. The results of the pre-test and post-test analyzed using Gain Score showed a value of 0.73, indicating a high increase in student learning achievement. This shows that the Augmented Reality (AR) application is effective in improving learning outcomes. Therefore, it can be concluded that there is a significant increase in student learning achievement before and after using AR-based applications.

4 Conclusion

The conclusions include: Based on the validity results, material experts obtained feasibility with a percentage of 88.5%, design experts obtained feasibility with a percentage of 87.5%, and student responses regarding feasibility obtained a percentage of 87.5% in the first trial, namely 25 students and 90.42% in the second trial, namely 25 people. Based on the data from the validation results, the Augmented reality-based application for personalization of elementary school mathematics learning developed is included in the criteria of being very good and suitable for use. And based on classical data, the average reaches 90 with a Gain Score of 0.73 in the high category. And the student questionnaire responses regarding effectiveness reached 88% from 25 people. Based on this data, an augmented reality-based application for personalizing elementary school mathematics learning is said to be effective in learning assuming higher elementary school mathematics scores when using the AR application.

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