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THE DEVELOPMENT OF MATHEMATIC LEARNING MODULE BASED ON PROJECT BASED LEARNING USING AUGMENTED REALITY TO IMPROVE THE CONCEPTUAL UNDERSTANDING ABILITY

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Abstract: *This study aims to produce a valid, practical, and effective Mathematics Learning Module Based on Project-Based Learning Using Augmented Reality to Improve Conceptual Understanding Ability, specifically for the topic of Quadratic Equations and Functions. The research employs a development research approach with the ADDIE development model (Analysis, Design, Development, Implementation, and Evaluation). The subjects of this study are 34 students from class X-12 at MAN 1 Medan. The object of this study is the Mathematics Learning Module Based on Project-Based Learning Using Augmented Reality. The instruments used include material and media validation questionnaires, teacher and student response questionnaires, and tests to assess students' mathematical conceptual understanding abilities. The results of the study indicate that: (1) The validity of the learning module, based on expert assessments of material and media, received scores of 87.41% and 82.97% respectively, categorized as very valid; (2) The practicality of the learning module, based on teacher assessments, was 93%, categorized as Very Practical, while the practicality score based on student assessments was 81%, also categorized as Very Practical; (3) The effectiveness of the learning module, measured by the classical student learning completion rate, was 97%, with an average conceptual understanding ability score of 92.65%, and the learning time used did not exceed that of normal lessons; (4) The improvement in students' Mathematical Conceptual Understanding Ability after learning using the developed Learning Module showed a significant progress, with an n-gain value in the High category, averaging 0.7.Based on the results of this study, the Module Based can be considered and categorized as valid, practical, and effective. The learning module can serve as an alternative for teachers in their teaching activities and as a guide for other researchers in developing learning modules that align with the characteristics of the application of Project-based Learning.*

Keywords: *Mathematics Learning Module, Project-Based Learning, Augmented Reality, Mathematical Conceptual Understanding, Quadratic Equations and Functions.*

BACKGROUND

According to (Fadilla & Purwaningrum, 2021), education is a concept and method designed to establish a learning system and environment that enable students to develop their potential in skills, intelligence, spiritual strength, personality, and noble character. The primary goal of mathematics education is to equip students with the ability to apply mathematical concepts in daily life, as mathematics is essential for understanding, mastering, and solving various social, economic, and environmental problems. Furthermore, mathematics is closely related to abstract ideas and concepts (Maksum & Fitria, 2021).

Conceptual understanding in mathematics refers to the ability to comprehend mathematical concepts, operations, and relationships, including the meaning of symbols, diagrams, and procedures used (Iskandar et al., 2021).

Conceptual understanding develops

through exploring the meaning of concepts rather than repeated practice. It begins with (1) factual knowledge, where students recognize and recall information when needed. As they progress, they move beyond memorization and develop (2) comprehension, understanding the meaning behind mathematical procedures. This enables them to (3) apply and adapt mathematical ideas to new situations. The depth of their conceptual understanding depends on (4) analysis, which involves making meaningful connections while exploring mathematical structures. A key indicator of this understanding is (5) synthesis, where students can represent mathematical situations in multiple ways and recognize how different representations serve various purposes. Finally, (6) evaluation allows students to see relationships between concepts and procedures, justify why certain facts follow from others, and construct logical arguments. Learning with a focus on understanding enhances student engagement, as they begin to see how mathematical ideas interconnect to form a cohesive framework of knowledge (Kaswar, 2021) by the researcher, along with the results of the diagnostic test, provided an overview of students' learning abilities. This diagnostic test was designed to assess their level of understanding and was administered to 34 students from class X-12 at MAN 1 Medan. The results of this test serve as a basis for determining the next instructional steps that best align with students' needs. In its implementation, the diagnostic test consisted of five questions, each representing key indicators of mathematical conceptual understanding. The following table presents the analysis results of the diagnostic test based on students' conceptual understanding in mathematics

Quadratic equations and quadratic functions are a crucial part of the mathematics curriculum at the high school level and are often used in various fields, including physics and engineering. However, many students encounter difficulties in understanding the relationship between quadratic equations and their graphs (Andriyani & Buliali, 2021).

The AR module allows students to interact directly with graphs, so they can easily understand the positions of vertices, axes of symmetry, and roots of equations through manipulating the graph in front of them. The main aim of developing this module is to present interactive and fun learning, so that students can quickly understand the application of quadratic concepts in everyday life. The development of this learning module based on Project Based Learning (PjBL) using Augmented Reality (AR) is expected to provide benefits not only for students, but also for teachers, as an effective teaching aid, creating an interesting and easy-to-understand learning experience. Based on the problems that have been explained, The Development of Learning Module Based on Project Based Learning (PjBL) Using Augmented Reality (AR) to Improve Conceptual Understanding Mathematics Students Grade X MAN 1 Medan students is worthy of development. This research aims to produce learning modules that are valid, practical and effective in learning mathematics, especially on the subject of quadratic functions (Gosawa, 2023).

The use of AR not only visualizes abstract concepts, but also makes it more interactive, so that students can interact directly with the material. Thus, this module has the potential to overcome the difficulties students face in understanding mathematics and improve the overall quality of learning. In summary, there is a distinct gap between the expectation of mastering quadratic functions through contextual projects and reality of practical constraints (time and abstract visualization) in schools. This research attempts to bridge this gap by developing a learning module that integrates AR into the PjBL model, offering a solution that is both contextually rich and time-efficient (Haryani et al., 2024).

METHODS

This type of research is development research (*Research & Development*) using the ADDIE development model (*Analysis, Design, Development, Implementation, and Evaluation*). This research applies the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) development model introduced by (Huwaida Nisrina et al., 2021).

RESULTS AND DISCUSSION

Research Results

This study employs a research and development (R&D) approach to develop a project-based mathematics learning module integrated with Augmented Reality (AR) aimed at improving students' mathematical conceptual understanding. The results indicate that the validity of the learning module, based on evaluations by material and media experts, reached 87.41% and 82.97%, respectively, both categorized as *very valid*. The practicality of the module achieved a score of 93% based on the teacher's assessment and 81% based on students' assessments, both classified as *very practical*. Furthermore, the effectiveness of the module was demonstrated by students' classical learning completeness of 97%, an average achievement of mathematical conceptual understanding of 92.65%, and learning time that did not exceed conventional instruction. In addition, students' mathematical conceptual understanding skills improved after using the developed module, as indicated by a high N-gain value with an average of 0.7. Based on these findings, the developed learning module on Quadratic Equations and Quadratic Functions is considered feasible, valid, practical, and effective.

Description of the Learning Module Development Stage

The product developed in this study is a Mathematics Learning Module Based on Project-Based Learning Using Augmented Reality (AR) on the topic of quadratic equations and functions, aimed at improving the conceptual understanding of mathematics among students at MAN 1 Medan.

In the process of developing the learning module, the first step involved designing a storyboard that serves as the fundamental framework outlining the sequence and description of each display within the module. This storyboard guided the development of the Augmented Reality learning content and its visual structure. An illustration of the display design of the AR learning module is presented in Figure 1.

Figure 1 Display of the AR Learning module

The Augmented Reality (AR) learning module is designed to support the teaching of Quadratic Equations and Quadratic Functions for Grade X senior high school students. The module cover features a visually engaging combination of blue, white, yellow, and purple, accompanied by illustrations representing Augmented Reality technology to attract learners' attention. The learning objectives are formulated in alignment with the Merdeka Curriculum and the Pancasila Student Profile, emphasizing students' conceptual and contextual understanding of quadratic concepts. A hierarchical concept map is provided to present an overview of the material and illustrate the relationships between key concepts. The module also includes clear instructions for use, offering two display modes: a real-world view utilizing direct AR through the device camera and a 3D display mode. The content is structured

into two main topics, namely Quadratic Equations and Quadratic Functions, and is complemented by project-based activities that encourage students to explore and apply these concepts actively. Finally, the module concludes with a concise and systematic summary to reinforce students' understanding of the presented material.

Analysis of Improvement in Students' Mathematical Concept Understanding Ability

1. Description of the Improvement for Each Indicator

The improvement in students' mathematical concept understanding ability based on the indicators using the Mathematics Learning Module Based on Project-Based Learning Using Augmented Reality (AR) is presented in the following Table 2.

Table 1 Improvement in Students' Mathematical Concept Understanding Ability for Each Indicator

No	Indicator	Score			
		Pretest	Posttest	Average	Improvement
1	Restating a concept	58,82%	100,00%	79,41%	41,18%
2	Classifying objects based on whether they meet the necessary criteria to form a mathematical concept	52,94%	91,18%	72,06%	38,24%
3	Representing concepts through adaptive mathematical reasoning representations	20,59%	100,00%	60,29%	79,41%
4	Connecting various mathematical concepts (both internally and externally)	0,00%	79,41%	39,71%	79,41%

The Table 1 illustrates the improvement in students' mathematical concept understanding ability across each indicator. All indicators show significant progress from pretest to posttest, with the most substantial improvement seen in students' ability to represent concepts and connect various mathematical ideas. This suggests that the developed learning module effectively enhanced students' conceptual understanding.

2. Description of the Improvement in Students' Mathematical Concept Understanding Ability Through N-Gain Value

In this study, the improvement in students' mathematical concept understanding ability is reviewed based on the scores obtained from the pretest and posttest. The results of the pretest and posttest are then analyzed based on the overall N-gain, which will be presented in the following Table 3.

Table 2 N-gain Value

Student Code	Pretest	Posttest	Posttest - Pretest	Max. Score - Pretest	N-Gain	Category
S-1	56,25	87,50	31,25	43,75	0,71	High
S-2	28,13	87,50	59,38	71,88	0,83	High
S-3	34,38	93,75	59,38	65,63	0,90	High
S-4	43,75	84,38	40,63	56,25	0,72	High
S-5	50,00	81,25	31,25	50,00	0,63	Middle
S-6	50,00	81,25	31,25	50,00	0,63	Middle
S-7	40,63	84,38	43,75	59,38	0,74	High
S-8	87,50	96,88	9,38	12,50	0,75	High
S-9	46,88	84,38	37,50	53,13	0,71	High
S-10	25,00	81,25	56,25	75,00	0,75	High
S-11	43,75	87,50	43,75	56,25	0,78	High
S-12	37,50	81,25	43,75	62,50	0,70	High
S-13	59,38	87,50	28,13	40,63	0,69	Middle
S-14	81,25	87,50	6,25	18,75	0,33	Middle
S-15	34,38	81,25	46,88	65,63	0,71	High
S-16	40,63	84,38	43,75	59,38	0,74	High
S-17	68,75	87,50	18,75	31,25	0,60	Middle
S-18	50,00	84,38	34,38	50,00	0,69	Middle
S-19	46,88	87,50	40,63	53,13	0,76	High
S-20	56,25	81,25	25,00	43,75	0,57	Middle
S-21	34,38	81,25	46,88	65,63	0,71	High
S-22	43,75	84,38	40,63	56,25	0,72	High
S-23	62,50	87,50	25,00	37,50	0,67	Middle
S-24	53,13	65,63	12,50	46,88	0,27	Low
S-25	43,75	84,38	40,63	56,25	0,72	High
S-26	84,38	96,88	12,50	15,63	0,80	High
S-27	34,38	84,38	50,00	65,63	0,76	High
S-28	50,00	84,38	34,38	50,00	0,69	Middle
S-29	46,88	90,63	43,75	53,13	0,82	High
S-30	50,00	87,50	37,50	50,00	0,75	High
S-31	40,63	81,25	40,63	59,38	0,68	Middle
S-32	65,63	93,75	28,13	34,38	0,82	High
S-33	43,75	84,38	40,63	56,25	0,72	High
S-34	59,38	87,50	28,13	40,63	0,69	Middle
Total	1693,7	2906,25			23,77	
Average	49,82	85,48			0,70	High

Based on the Table 2 above, the average gain obtained is 0.7, which falls under the "high" category. According to the N-Gain calculation criteria, a minimum value of ≥0.6 indicates that the test results show an improvement in students' mathematical concept understanding ability.

Discussion of Reseach Results

The Mathematics Learning Module Based on Project-Based Learning Using Augmented Reality (AR) was developed using the ADDIE model with five stages: (1) Analysis, (2) Design, (3) Development, (4) Implementation, and (5) Evaluation. After passing through all the development stages, the Mathematics Learning Module Based on Project-Based Learning Using Augmented Reality (AR) was produced, demonstrating quality in terms of validity, practicality, and

effectiveness.

Based on the data analysis obtained from the field trial, the findings are as follows: (1) The teaching module, tests, and the Mathematics Learning Module Based on Project-Based Learning Using Augmented Reality (AR) developed were classified as very valid, (2) The Mathematics Learning Module Based on Project-Based Learning Using Augmented Reality (AR) is highly practical, (3) The developed Mathematics Learning Module Based on Project-Based Learning Using Augmented Reality (AR) is effective, and (4) There was an improvement in students' mathematical concept understanding ability through the developed Mathematics Learning Module Based on Project-Based Learning Using Augmented Reality (AR).

From the evaluation results of each stage of the module development, it can be concluded that the developed learning module met the criteria of validity, practicality, and effectiveness. Therefore, the ADDIE model development cycle to produce a high-quality product has been completed.

CONCLUSIONS

Based on the analysis and discussion of the results in this study, several conclusions can be drawn as follows: (1) The Mathematics Learning Module Based on Project-Based Learning Using Augmented Reality (AR), according to the validator's ratings, falls into the very valid category with an average percentage score for the material of 82.97% and an average score for the media of 84.84%. The validation result for the Teaching Module averaged 87.41%, and the validation results for the tests measuring the improvement of mathematical concept understanding were considered valid with revisions by experts. (2) The Mathematics Learning Module Based on Project-Based Learning Using Augmented Reality (AR) is categorized as very practical, with a teacher's response score of 93% and an overall student response of 81%. (3) The Mathematics Learning Process using Mathematics Learning Module Based on Project-Based Learning Using Augmented Reality (AR) meets the effectiveness criteria, as seen from: (a) The classical learning completeness, which reached 97%. (b) The achievement of each learning objective/indicator was met: for Indicator 1 of mathematical concept understanding, the score was 100%; for Indicator 2, the score was 91.18%; for Indicator 3, the score was 100%; and for Indicator 4, the score was 79.41%. (c) The learning time did not exceed the usual time allocated for lessons. (d) The students' understanding of mathematical concepts has improved, as seen from the increased ability in each mathematical concept indicator and the high N-Gain value of 0.7 between the pretest and posttest.

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