CHAPTER I

INTRODUCTION

1.1 Backgroud

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. In this context, one of the disciplines that plays a significant role in developing these abilities is mathematics. Mathematics is a field of study that holds a crucial role in the advancement of technology and science, as well as in fostering logical, systematic, analytical, critical, and creative thinking. Due to its significance, mathematics is taught at all levels of education, from elementary school to higher education. 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 (Anisa Meidianti *et al*., 2022).

According to the report released on December 5, 2023, the *Organization for Economic Cooperation and Development* (OECD), through the *Programme for International Student Assessment* (PISA) 2022, ranked Indonesia 68th out of 81 countries. The findings indicate a decline in average scores across all three assessed subjects compared to PISA 2018. Additionally, the percentage of students who did not reach Level 2 increased by 5% compared to 2012. In mathematics, Indonesia scored 366, which is 106 points below the global average. Only 18% of Indonesian students achieved at least Level 2 in mathematics, significantly lower than the OECD average of 69%. Based on this data, it can be concluded that the majority of students in Indonesia (82%) have not yet reached the minimum competency level in mathematics, which may hinder their ability to apply mathematical concepts in daily life.

Mathematics is a subject that plays a crucial role in education, from elementary school to higher education (Rahayuni *et al*., 2020). Conceptual understanding is a fundamental aspect of learning mathematics, as students must grasp basic concepts before solving problems and applying their knowledge to real-life situations (Anisa Meidianti *et al*., 2022). Mastering these concepts from an early stage is crucial for progressing to more advanced levels of learning. Students who have a strong understanding of mathematical concepts are more likely to solve problems effectively, whereas those who lack this understanding tend to struggle. This difficulty arises due to the interconnected nature of mathematical concepts, where a solid grasp of one concept supports the comprehension of others. Therefore, mathematics education should not solely focus on repetitive practice or solving similar problems until students memorize the procedures. Instead, it should emphasize deep conceptual understanding to ensure meaningful learning (Putri, Iswara, & Hakim, 2021).

In 2001, the National Research Council, in their report *Adding it up: Helping children learn mathematics* states that there are five strands of mathematics proficiency, one of which is conceptual understanding. Conceptual understanding in mathematics refers to the ability to comprehend mathematical concepts, operations, and relationships, including the meaning of symbols, diagrams, and procedures used (Kilpatrick, J., *et al.,* 2001). 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 (Math Assessment Resource Service, 2017).

Understanding concepts is one of the competencies that students must master in learning mathematics (Depdiknas, 2006:346). Based on Minister of National Education Regulation Number 22 of 2006, the objectives of teaching mathematics in schools are: (a) understanding mathematical concepts, explaining the relationship between concepts, and applying concepts or algorithms flexibly, accurately, efficiently and precisely in solving problems, (b) using reasoning in patterns and properties, carrying out mathematical manipulations to make generalizations, compiling evidence, or explaining mathematical ideas and statements, (c) solving problems which includes the ability to understand the problem, design mathematical models, complete the model, and interpret the solution, (d) communicate ideas through symbols, tables, diagrams, or other media to clarify problems, and (e) appreciate the importance of mathematics in everyday life, including having curiosity, attention, interest, as well as a tenacious and confident attitude in solving problems (Depdiknas, 2006).

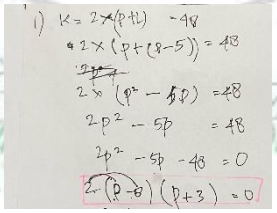
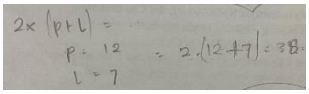
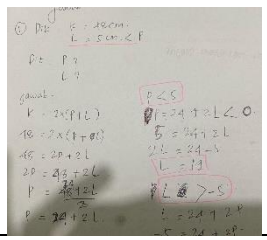
The study conducted by Sitorus *et al.* (2022) indicates that students' mathematical comprehension remains relatively low, with only three students achieving scores above the minimum competency standard (KKM), while ten students did not meet the required threshold. The average score from the distributed questionnaire was 72.31. These findings align with the research by Nurul Choiriyah (2023), which revealed that students struggle to solve word problems that differ from the examples previously explained by the teacher. This difficulty arises from students' tendency to memorize formulas rather than understanding how to apply them in problem-solving. Based on these findings, it can be concluded that students' conceptual understanding, particularly in statistics, remains low.

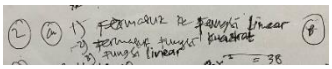
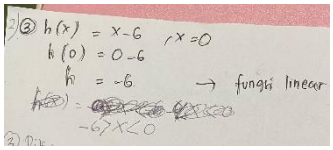
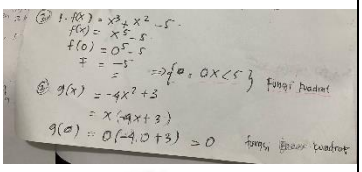
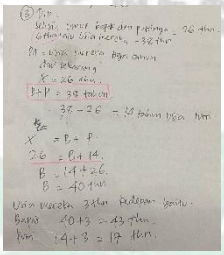
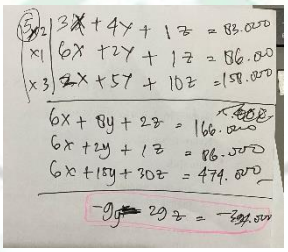
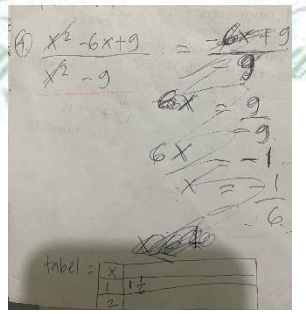
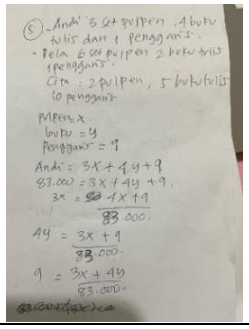
Furthermore, data from the *Programme for International Student Assessment* (PISA) highlights a significant gap in mathematics education between

Indonesia and countries with the world's best education systems. This suggests that students' comprehension has not yet reached an optimal level, emphasizing the urgent need for a learning approach that prioritizes conceptual understanding over rote memorization.

The observations conducted 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.

Table 1. 1 Student Answer Sheet (Diagnostic Test)

No.	Indicator of Mathematics Conceptual Understanding	Students Answer	Description
1	Restating the concepts that have been learned	  	Only 13 out of 34 students, approximately 38.2%, correctly answered the questions related to the indicator of restating the concept. Meanwhile, the remaining 61.7% failed to do so. Many of them still struggle to apply the concepts they have previously learned.

2.	Classifying objects based on whether they meet the necessary conditions to form a mathematical concept	  	Only 23 out of 34 students, or approximately 67.6%, correctly answered the questions on that indicator. Meanwhile, the remaining 32.3% still struggled to categorize objects based on specific characteristics.
3.	Representing concepts through adaptive mathematical reasoning representations		Based on the analysis results, only 15 out of 34 students, or approximately 44.11%, successfully answered the question for this indicator. Meanwhile, 55.88% of students answered incorrectly.
4.	Connecting or relating various mathematical concepts (both internally and externally)	  	Based on the diagnostic test results, only 10 out of 34 students, or approximately 29.41%, correctly answered the question under the indicator "Connecting or relating various mathematical concepts." Meanwhile, 70.58% of students still struggled with calculations and connecting different mathematical concepts within the learning process.

Based on the analysis of the diagnostic test results in Table 1.1, a significant number of students struggled to answer the questions. Out of 34 students, only 3 managed to answer all questions correctly, accounting for approximately 8.82%. Meanwhile, the remaining 31 students made errors in responding to questions related to conceptual understanding in mathematics. The diagnostic test results indicate that students did not meet the Minimum Mastery Criteria (KKM), as their average scores were below 80. Additionally, only 50% of students were able to meet the KKM threshold, highlighting that their conceptual understanding in mathematics remains relatively low.

According to an interview with the teacher, students' poor understanding of mathematical concepts is due to their tendency to memorize formulas without truly grasping the underlying concepts. As a result, when faced with different types of problems, they struggle to comprehend and determine the appropriate mathematical model to use. Moreover, they are not yet able to express their ideas for solving problems effectively. This issue arises because students are not accustomed to solving problems based on indicators of conceptual understanding. Additionally, the teacher mentioned that another contributing factor could be that Grade X is a transition period from junior high school, meaning students still need to strengthen their understanding of mathematical concepts.

Another issue identified is related to the use of teaching materials. Interview results indicate that the teaching materials used in schools remain limited in variety. So far, instructional resources primarily consist of printed textbooks. Printed textbooks represent traditional learning materials that have not yet been digitized, Additionally, the main motivational factor for students in understanding mathematics, particularly quadratic functions, lies in the relevance of the material to real-life situations and their active participation in the learning process. Although widely used printed textbooks provide a clear structure, students often struggle to grasp quadratic functions due to their abstract nature and the absence of interactive components that connect the material to practical applications. Teachers tend to explain the concepts theoretically without incorporating interactive learning media,

relying solely on printed textbooks. These textbooks typically have simple designs and focus only on core material. This situation not only diminishes students' interest in reading but also limits their conceptual understanding, reducing it to mere memorization of formulas without comprehending the underlying logic.

Most students, when asked about subjects they do not like, they often answer mathematics (Usman, *et al*, 2023). According to Harefa and Laia (2021), and Hasiru *et al*. (2021), the characteristics of mathematics which tend to be abstract cause difficulties for students in understanding this lesson. Abstract concepts that are difficult for students to understand can be made more concrete with the help of computer technology, making it easier for them to understand imaginative mathematical concepts (Usman, *et al*., 2023). The use of technology in the mathematics learning process has been proven to be able to improve the quality of learning (Hamidah *et al.*, 2020). Rhilmanidar (2020) states that computer-based media is very necessary in learning mathematics to help students learn more effectively, meaningfully and deeply.

Students' comprehension of mathematical concepts plays a crucial role in the mathematics learning process. Educators should be capable of demonstrating the connections between various concepts within a topic. In mathematics education, conceptual understanding serves as a foundation for developing other essential skills. To support this, teachers need to design and implement well-structured mathematics lessons (Damayanti *et al.*, 2024). One strategy to enhance student development is to design teaching materials that are comprehensive, self-contained, and structured around a series of learning activities (Darmastuti, 2023). Several factors influence the effectiveness of the learning process, including the role of teachers, the use of modules, and the implementation of teaching models. Ineffective teaching approaches, combined with inconsistent strategies in mathematics instruction, can further hinder student learning. Project-Based Learning (PjBL) is considered one of the most relevant approaches, particularly with the adoption of the *Kurikulum Merdeka*. PjBL is a learning method that introduces new concepts by using real-world problems as a starting point. This

approach encourages students to gain a deeper understanding of a topic and broaden their knowledge by integrating multiple disciplines (Ramadhanti, N., *et al.*, 2023).

One effective way to improve students' understanding of mathematical concepts is to use interesting and interactive learning media. Well-designed learning media can help students more easily understand complex material, such as mathematical concepts. One form of learning media that can be used is learning modules. This module can be designed systematically by displaying the material visually, accompanied by simple explanations, and equipped with challenging practice questions. By using interesting learning modules, students will be more motivated to learn and their understanding of the concepts being taught will be deeper.

Learning modules are designed to assist students in achieving clearly defined and measurable learning objectives. Additionally, well-structured and appropriately designed modules can enhance the quality of the learning process (Darmastuti, 2023). Modules are key elements in teaching materials that require innovation to increase their effectiveness. This innovation is not only limited to the content presented, but also includes various other aspects related to the delivery of the module (Fauzan, M., 2021). As a learning tool, the module is designed to facilitate students in understanding concepts in a more structured and independent way. Modules consist of several components, including learning objectives, materials, exercises, and evaluations, so students can learn at their own pace. Research shows that the application of modules in the learning process can significantly increase students' understanding of mathematical concepts, one of which is Research conducted by Dhea Yolanda, Sugiyanti, and Muhammad Prayito (2023) shows that the use of ethnomathematics-based e-modules can improve understanding of mathematical concepts in students at SMAN 1 Grobogan. This research was motivated by limited learning resources and the low ability of students to understand mathematical concepts which only reached 59,33%. The results show that this e-module is effective in increasing students'

understanding of mathematical concepts, with 79% of students expressing a need for electronic learning media.

Digital transformation is a change in an activity that uses information and communication technology (ICT) to provide convenience and increase the efficiency of results (Maksum, 2021). Educational technology is very important to support the learning process. By utilizing technology, teaching and learning activities can take place optimally, so that the goals that have been set can be achieved. Information technology can function as a driver of a nation's progress. One of the significant impacts of technology is the developments that occur in the education sector (Simanjuntak *et al.*, 2020). In line with this, the application of technology in mathematics learning can be a solution to overcome the challenges faced by students.

The world of education needs to adapt to ongoing changes. This challenge includes developing innovation in the learning process, use of media, and skills needed in the digital era, as well as preparing students to face the future. Therefore, the education sector must implement sustainable innovation, including the use of Augmented Reality (AR) technology. One of the latest technologies that is currently popular is Augmented Reality (AR), a technology that is able to change two-dimensional (2D) objects into three-dimensional (3D) which are more lively and interactive. Augmented Reality is a technology that combines two-dimensional (2D) or three-dimensional (3D) virtual objects into a three-dimensional real environment, which allows interactive interactions in real time (Alzahrani, 2020).

With AR, abstract concepts can be visualized more clearly, thereby increasing understanding of the structure of an object. Even though AR technology is no longer foreign to Indonesia, its application in education is still limited. In fact, AR is very suitable as a learning medium because it can clarify students' understanding of the structure of objects which are usually only studied through two-dimensional images in textbooks. For this reason, it is necessary to develop creativity in mathematics learning, so that this subject can be taught in

a way that is interesting and relevant to everyday life. In this context, teachers need to create a conducive learning environment by using appropriate learning models, so that students not only passively receive the material but also actively search for and understand the material independently. With AR technology, understanding mathematical concepts that were previously difficult to visualize will become clearer and more concrete, thereby increasing students' ability to understand mathematical structures and patterns in more depth.

The application of Augmented Reality (AR) in the field of education has demonstrated significant capabilities in helping students understand abstract mathematical concepts, such as quadratic equations and quadratic functions. With AR, students can observe mathematical concepts in a visual and interactive form, which helps connect abstract ideas with practical applications in the real world. This technology enables better understanding and enriches students' learning experiences. The integration of Augmented Reality (AR) significantly enhances students' competence and understanding of material. Research by Nugraha *et al.*, (2021) demonstrates that students experience an engaging, stimulating, and interactive learning environment through AR media, which fosters better comprehension of classroom topics. Furthermore, Setyawan *et al*. (2020) highlight that AR serves as a valuable tool for visualizing abstract concepts and models, facilitating a deeper understanding of various objects. The engaging and informative nature of AR makes it an effective educational resource. There are several applications that utilize 3D augmented reality, one of which is Assemblr Edu. This specific platform is designed to support educational needs, particularly in teaching and learning activities. Assemblr Edu offers features like classes, topics, scans, and profiles, all of which enhance its functionality. Since the application is rooted in augmented reality, it provides a more engaging and interactive learning experience for students (*Majid et al*., 2023).

Augmented Reality (AR) technology is attracting increasing attention in the world of education, offering significant potential to enrich students' learning

experiences with interactive, real-time content. The development of AR-based learning modules for the Android platform has become a rapidly growing research area. With the large population of Android users and advances in AR technology, the integration of AR in learning is now more accessible to students and educators. Through a systematic approach in designing AR-based interactive learning modules, it is hoped that a deeper and more interesting learning experience will be created, which can facilitate understanding of complex concepts and increase student engagement (Pathorrahman, *et al*., 2024). Through AR technology, students can see real-life examples of abstract concepts in mathematics, such as graphing quadratic equations in 3D, which helps them understand the material better.

For example, research conducted by Pathorrahman, Chandra Anugrah Putra, and M. Noor Fitriyanto from Muhammadiyah University Palangka Raya in 2024 shows that the use of AR technology can create a more interesting and in-depth learning experience. By integrating AR concepts in content design and using platforms like ARCore or Unity, these learning modules not only increase student engagement but also help them understand complex concepts better. This research also emphasizes the importance of the testing and evaluation process with target users to ensure the modules developed are truly effective and useful in the context of digital education.

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. Quadratic equations are the main focus for tenth grade students, where although this topic has been taught at junior high school level, the level of difficulty increases in tenth grade with the addition of various methods for finding roots and solving algebraic problems (Andriani & Nuryana, 2018).

The use of Augmented Reality (AR) in learning quadratic equations and quadratic functions provides students with the opportunity to directly observe the

parabolic trajectory of a moving object, such as a thrown basketball or a kicked-soccer ball. For example, the movement of a basketball that bounces along a parabolic path can be predicted using a quadratic equation, where students need to understand how to determine the peak point to determine the maximum height of the throw. Additionally, AR allows students to see how quadratic functions can be used to predict the movement of objects in everyday life, making it easier to understand more complex concepts. With better interaction and clear visualization, students can relate mathematical theory to practical applications in the real world, thereby increasing their motivation and understanding of the material.

Although Project-Based Learning is effective, it often encounters constraints regarding time efficiency and the availability of physical facilities. For instance, conducting a real-world project to analyze a basketball trajectory requires a sports field and significant time for setup and execution. Augmented Reality (AR) addresses this limitation by bringing the project simulation directly into classroom. This technology allows students to visualize and analyze the parabolic trajectory virtually, thereby optimizing the project time without sacrificing the contextual learning experience. This visualization helps students grasp that the parabolic curve is not just a line on a paper, but a representation of a real-world phenomenon, thereby strengthening their conceptual understanding beyond rote memorization. The need to develop interactive learning module based on Project Based Learning (PjBL) using Augmented Reality (AR) is increasingly urgent to increase students' understanding of mathematical concepts, especially equations and quadratic functions. Considering the challenges students face in understanding abstract material, this learning module is expected to provide visualization and a more in-depth and concrete learning experience.

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. Additionally, this module is designed to provide immediate feedback to students during the learning process, allowing them to understand how real concepts in quadratic equations can be translated into graphs. In this way, it is hoped that students can be more involved in the learning process, which will ultimately improve their overall learning outcomes. 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.

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.

1.2 Problem Identification

Based on the background of the problem above, the problem identification in this research is:

1. Students consider that mathematics is a difficult subject, which results in a lack of understanding of mathematical concepts.

2. Abstract mathematical concepts are difficult to understand without clear visualization, which can help students connect theory with practice.
3. The use of conventional modules that are less interactive causes students to feel monotonous and less involved in learning.
4. The learning modules currently used have a simple design and only cover core material, there by reducing students' interest in reading.
5. The use of 2D images as a learning medium is considered less effective because it only provides one point of view without interaction.
6. Development of learning modules Based on Project Based Learning using *Augmented Reality* (AR) has never been applied in the learning process.

1.3 Scope of Study

The scope of this research is Development of Mathematics Module Based on Project Based Learning Using Augmented Reality (AR) to Improve the Conceptual Understanding Mathematics which is focused on grade X students of MAN 1 Medan.

1.4 Scope of Problem

Based on the background and identification of the problem above, it is a fairly broad and complex problem so it is necessary to limit the problem, so that this research is more focused and achieves the expected goals, the author limits the problem as follows:

1. This research uses the Research and Development (R&D) research method with the ADDIE research model (Analysis, Design, Development, Implementation, and Evaluation).
2. This research will use an Learning Module based on Project Based Learning using AR developed with the Assemblr Edu application, as an alternative to printed modules with 2D images that are less interactive.
3. This learning module was specifically tested on the Mathematics subject, Quadratic Functions, Grade X MAN 1 Medan

4. The development in question is the development an Learning Module using AR designed to present real concepts/applications of quadratic functions visually and interactively, especially for the material on the graph of quadratic functions in order to increase learning effectiveness.
5. The development of this learning module focuses on improving the ability to understand mathematical concepts of class X-12 MAN 1 Medan students
6. The development of this learning module based on Project Based Learning using AR is a new innovation that has never been implemented in the learning process at MAN 1 Medan, especially to increase understanding of the concept of quadratic functions.

1.5 Research Question

Based on the background and limitations of the problem above, the problem formulation in this research is as follows:

1. How is the Validity of the Mathematics Learning Module Based on Project-Based Learning Using Augmented Reality (AR) that has been developed?
2. How is the Practicality of the Mathematics Learning Module Based on Project Based Learning Using Augmented Reality (AR) that has been developed?
3. How is the Effectiveness of the mathematics learning process facilitated by the Mathematics Learning Module Based on Project Based Learning Using Augmented Reality (AR) that has been developed?

1.6 Study Objectives

The objectives of this research are as follows:

1. To determine the Validity of the Mathematics Learning Module Based on Project Based Learning Using Augmented Reality (AR) that has been developed.

2. To determine the Practicality of the Mathematics Learning Module Based on Project Based Learning Using Augmented Reality (AR) that has been developed.
3. To determine the Effectiveness of the mathematics learning process facilitated by the Mathematics Learning Module Based on Project Based Learning Using Augmented Reality (AR) that has been developed.

1.7 Research Purposes

Based on the research objectives above, the benefits of this research are as follows:

Theoretically

a. This research contributes to the development of Mathematics Learning Module Based on Project Based Learning Using Augmented Reality and provides a step-by-step guide for designing mathematics learning modules.
b. The resulting product is expected to be a valuable reference for the development of mathematics learning modules using AR in the future.
c. This research can be a reference for similar research that will be carried out in the future.

Practically

a. For Researchers

   This research enriches researchers' insight and skills in compiling interesting and effective mathematics learning modules based on project based learning using AR, as well as increasing researchers' abilities in creating new learning products that are beneficial for students' mathematics learning.

b. For teachers

   This research offers a new alternative in developing teaching materials that can improve the quality of mathematics learning, thereby helping teachers in creating more interesting learning experiences for students.

c. For students

Students will gain a more interesting learning experience through mathematics learning modules based on project based learning using AR, which can increase their interest in learning mathematics. This increase in interest is expected to have a positive impact on students' learning outcomes and understanding of mathematical concepts.

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