# Developing of a Teaching Module Based on Guided Discovery Learning Assisted by Augmented Reality (AR) on polyhedra Material for Students' Conceptual Understanding in Phase D

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**ABSTRACT:** This study aims to address the issue of students' low conceptual understanding in geometry learning, particularly in the topic of polyhedra, which tends to be abstract. Many students struggle to visualize three-dimensional shapes due to the lack of interactive, student-centered learning media. To overcome this challenge, a teaching module based on Guided Discovery Learning, supported by Augmented Reality (AR) with GeoGebra, was developed to enhance students' mathematical conceptual understanding. The research employed a Research and Development (R&D) method using the 4-D model (Define, Design, Develop, and Disseminate). Data were collected through validation sheets, classroom observations, learning style questionnaires, student response questionnaires, and pre-test and post-test assessments. The results showed that the developed teaching module was valid, practical, and effective. The instrument validation scores for the teaching module were 4.47, for the LKPD (student worksheet) 4.30, and for the pre-test and post-test questions 4.40, all categorized as valid. Practicality was indicated by an implementation observation score of 4.47 (high category) and a positive student response rate of 87%. The module's effectiveness was evidenced by a classical mastery percentage of 80.9% and an N-Gain score of 0.7 (moderate category), indicating a significant improvement in students' conceptual understanding of polyhedra under the *Kurikulum Merdeka*. Based on these findings, it is recommended that the Guided Discovery Learning-based teaching module, supported by Augmented Reality, be used as an innovative alternative for geometry instruction to improve students' mathematical conceptual understanding of the topic of polyhedra.

**KEYWORDS:** Augmented Reality, Conceptual Understanding, Guided Discovery Learning, GeoGebra, Teaching Module.

## INTRODUCTION

Mathematics is one of the key disciplines in human life and plays a significant role both directly and indirectly. (Ibrokhimovich & Mirzaxolmatovna, 2022). Mathematics can be observed in various aspects of everyday life, ranging from buying and selling activities to other tasks that involve mathematical concepts (Ojose, 2023). Mathematics education begins at the elementary school level and continues through high school, even becoming a common subject at the university level. Nevertheless, mathematics learning in schools still encounters several obstacles, particularly regarding students' conceptual understanding of mathematics.

The results of the study conducted by Kurnia and Hidayati (2022) show that one of the challenges students face when answering mathematical problem questions is their difficulty in applying concepts. Students need to have a strong understanding of mathematical concepts in order to apply geometric skills optimally in mathematics learning (Madimabe, 2022). Students who understand concepts are able to process information objectively, establish connections between various pieces of information, analyze the information, evaluate it, and draw conclusions (Patilima, 2022). Conceptual understanding is a crucial element in learning mathematics. With a solid grasp of concepts, students are able to solve mathematical problems more effectively (Wulandari, 2023). One of the elements that requires conceptual understanding in mathematics is geometry.

Geometry is a branch of mathematics that is closely related to the development of abstract concepts. Geometry learning does not merely rely on the transfer of knowledge but requires the formation of concepts through a series of activities directly carried out by students. (Fitria, 2022). In geometry, one of the areas of study is polyhedral. The teaching of polyhedral (solid figures with flat surfaces) often faces challenges due to the abstract nature of the concepts, where students frequently struggle to visualize three-dimensional shapes using only two-dimensional images presented in textbooks or on the chalkboard. (Fadilah & Muhtadi, 2024). This results in low conceptual understanding and poor comprehension of solid figure material among students. Learners are more likely to grasp mathematical concepts, particularly those related to solid figures, when they are able to visualize clearly and even represent the

shapes accurately (A. S. W. Siregar, 2022). Therefore, educators or teachers must introduce innovations or improvements in the learning process.

Based on the issues discussed, teachers are expected to create innovations in the learning process. In this era of rapidly advancing information and communication technology, learning approaches have undergone significant transformation. One notable innovation in the context of education is the use of Augmented Reality as a support tool in the learning process. (Yanuarto & Iqbal, 2022). Based on a study conducted by oleh Nazihah (2023), the use of GeoGebra in learning can help solve mathematical problems, indicating that GeoGebra is effective as a reference medium in mathematics instruction, particularly in geometry. However, the study did not yet incorporate Augmented Reality and suggested that AR could be further developed within the features of GeoGebra. The integration of AR technology can enrich students' learning experiences by presenting additional information through interactive visual elements (Kudsiah, 2023). This is also supported by a study conducted by Husnaidi (2023), which found that learning assisted by Augmented Reality has a statistically positive effect on learning outcomes, as it leads to an improvement in students' academic performance.

In addition to learning assisted by Augmented Reality, students' conceptual understanding of mathematics also requires the use of an appropriate instructional model, especially for topics such as polyhedral. Guided Discovery Learning offers a learning approach that encourages students to explore knowledge through a structured and guided discovery process actively. (Imawan & Ismail, 2022). This learning model encourages students to actively ask questions, engage in discussions, and construct their understanding through a guided discovery learning process.

This study is consistent with the results of an interview conducted with the Grade IX mathematics teacher at SMP Mishbahul Ulum Situbondo on March 25, 2025. The teacher explained that, in teaching, particularly on the topic of polyhedra (solid figures), they tend to use a lecture-based approach. Students listen to the teacher's explanation and then complete practice exercises. The teacher also stated that students' ability to understand mathematical concepts, especially on the topic of polyhedra, remains low. This is reflected in the high number of students who have not achieved learning mastery in evaluations. The one-way learning model, such as lecturing, is considered ineffective in helping students develop a deep understanding of mathematical concepts. Therefore, a more interactive and constructive learning approach is needed, such as Guided Discovery Learning supported by Augmented Reality, to enhance students' understanding of mathematical concepts optimally.

Based on the aforementioned explanation, there is a need for a breakthrough by utilizing Augmented Reality (AR) technology to improve students' conceptual understanding through the development of a teaching module based on Guided Discovery Learning, particularly on the topic of polyhedral. This approach aims to make mathematics learning more innovative and visual while also supporting the realization of *Profil Pelajar Pancasila*. Therefore, the researcher intends to conduct a study entitled " Developing of a Teaching Module Based on Guided Discovery Learning Assisted by Augmented Reality (AR) on polyhedra Material for Students' Conceptual Understanding in Phase D"

## RESEARCH METHODS

This study employs a research and development (R&D) method. According to T. Siregar (2023), research and development is a method used to produce a product and test its effectiveness. The research phase is conducted to gather data regarding user needs (needs assessment). Meanwhile, the development phase is carried out to produce the intended instructional product (Mesra, 2023). The procedure used in this research and development is the 4-D model developed by S. Thiagarajan, Dorothy S. Semmel, and Melvyn I. Semmel. The 4-D development model consists of four main stages: Define Design, Develop, and Disseminate.

The researcher chose the 4-D model based on several considerations, including: (1) this model offers more detailed, systematic, and precise stages, making it easier for the researcher to carry out the development of the teaching module; (2) it involves experts in the evaluation process to ensure the quality of the module before it is tested; (3) it includes trial, revision, and re-trial phases in multiple cycles to achieve optimal levels of practicality and effectiveness; and (4) it aligns well with the development of a guided discovery learning-based teaching module supported by augmented reality on polyhedral material to enhance students' conceptual understanding in Phase D.

The trial of the teaching module was conducted in Grade IX at Mishbahul Ulum Junior High School, Situbondo. The product developed in this study is a teaching module based on Guided Discovery Learning, supported by Augmented Reality, aiming to enhance students' conceptual understanding of mathematics. The material covered in this module focuses on polyhedra (three-dimensional shapes with flat surfaces) for Phase D of the Grade IX curriculum. The data collected in this study included (1)

validation sheets for the teaching module and student worksheets, (2) observation sheets for module implementation, (3) students' learning style questionnaires, (4) student response questionnaires, and (5) pre-test and post-test assessments. The data analysis methods used in this research are described as follows.

A. Validity data analysis

In this study, three experts conducted instrument validation: two lecturers from the Mathematics Education Study Program, one from University Nurul Jadid and the other from the College of Teacher Training and Education, and a mathematics teacher from Mishbahul Ulum Junior High School. Based on the validation results from the validators, the researcher then calculated the overall average score of all aspects ($V_a$). The teaching module is considered valid if the average score falls at least within the "valid" category according to the predetermined validation criteria.

Determining the instrument's validity involved a series of systematic stages. The first stage began with reviewing the validation data from each validator for each indicator in the developed instrument. Several validators assessed each indicator, and the average score of these assessments was calculated. This average score was obtained by summing the scores given by all validators for the indicator and dividing it by the number of validators involved.

After obtaining the average score for each indicator, the next step is calculating the average for each aspect. This calculation is done by summing all the average scores of the indicators within a particular aspect and then dividing the total by the number of indicators in that aspect. The resulting value represents the quality of each aspect of the instrument.

The final step is calculating the final validity score ($V_a$), the overall average value across all aspects. This value is obtained by summing the average scores of each aspect and then dividing the total by the number of aspects assessed. The Va score is the basis for determining the instrument's overall validity level.

Next, the level of instrument validity is categorized based on the range of the obtained $V_a$ (validity value). If the $V_a$ falls within the $1 \leq V_a < 2$ range, the instrument is classified as invalid. It is considered less valid if the $V_a$ is between $2 \leq V_a < 3$. When the Va is in the $3 \leq V_a < 4$ range, it is considered moderately valid. The instrument is classified as valid for values between $4 \leq V_a < 5$. Meanwhile, if $V_a = 5$, the instrument is declared highly valid. These validity categories serve as the basis for assessing the feasibility and appropriateness of an instrument before it is used in the data collection process of research or development.

B. Data Analysis of the Practicality of the Teaching Module

1) Analysis of the Implementation Observation Sheet of the Teaching Module

The initial step in analyzing the teaching module implementation's observation results is to recapitulate or record all observation data from each learning session. After that, the researcher calculates the average score for each observed indicator. This is done by summing all the observation scores given for a specific indicator across all sessions and dividing the total by the number of sessions conducted.

After the average score of each indicator is determined, the next step is to calculate the average score for each observation aspect. This is done by summing the average scores of all indicators within a particular aspect and then dividing the total by the number of indicators. In this way, the average score for each observation aspect is obtained.

The final step is determining the overall average score of all observed aspects. This is done by summing the average scores of all aspects and dividing the total by the number of aspects. This overall average score ($I_i$) is used to assess the extent of implementation or the practicality of the learning tools, such as the teaching module.

The obtained $I_i$ value is then compared to the implementation level categories of the learning tools based on specific intervals. According to the interpretation table, if $1 \leq I_i < 2$, the tool is categorized as "very low". if $2 \leq I_i < 3$, it is categorized as "low", for $3 \leq I_i < 4$, it falls into the "Moderate" category, while $4 \leq I_i < 5$ is categorized as "high"; and if $I_i = 5$, the tool is classified as "Very High".

Thus, the teaching module can be considered practical if the implementation observation results reach at least the "High" category based on the average score of all observed aspects.

2) Analysis of Students' Responses

The student response questionnaire is analyzed by calculating the response percentage using a percentage formula. This formula involves comparing the total score obtained by the students with the maximum possible score and then multiplying the result by 100%. This percentage reflects how students positively respond to use the developed teaching module. The higher the percentage, the more positive the students' responses are toward the learning process that has taken place.

After the percentage value is obtained, the data is categorized into five levels to assess the quality of student responses. These categories are as follows: "very good" if the response percentage is greater than $80\% < P \leq 100\%$, "Good" if it is between $60\% < P \leq 80\%$, "fair" for percentages between $40\% < P \leq 60\%$, "poor" for percentages greater than $20\% < P \leq 40\%$, and "very poor" if the percentage falls between $0\% < P \leq 20\%$ (Manap, 2014).

These categories are used to determine the extent to which the teaching module based on guided discovery learning, supported by augmented reality technology on the topic of three-dimensional shapes (phase D), is well-received by students. The teaching module is considered practical if the results of the student response questionnaire fall at least within the "good" category.

C. Data Analysis on Effectiveness

The effectiveness of the teaching module in this study is measured using the results of students' learning outcome assessments. The procedures carried out to analyse the effectiveness data of the teaching module are explained as follows.

1) Analysis of Student Learning Test Results

The effectiveness of the teaching module in this study is measured through students' learning outcome test results. This assessment aims to determine the extent to which the developed teaching module can improve students' understanding of the topic of solid figures. The data analysis process for effectiveness is carried out in several stages. The first step is to recapitulate all the test scores obtained by each student. Then, mastery learning is classified based on predetermined criteria: a student is considered to have achieved mastery if they score $\geq 70$ and not yet achieved mastery if the score is $< 70$.

The next step is to calculate the number of students who fall into the mastery category, which is then used to determine the level of classical mastery learning. A learning process is considered to have achieved classical mastery if at least 70% of the students reach the minimum mastery level. Conversely, if fewer than 70% of the students achieve mastery, the learning is considered not to have achieved classical mastery. This analysis serves as the basis for evaluating whether the teaching module used effectively supports students' learning achievement.

2) The improvement of students' critical reasoning skills is measured through the results of their mathematical concept understanding, which is then analysed using the N-Gain formula. The N-Gain formula is presented in the following equation.

$$g = \frac{st - si}{sm - si}$$

$g$ represents the N-Gain value, which indicates the improvement in students' understanding of mathematical concepts. $st$ Post-test score, which shows the level of improvement in understanding. Meanwhile, $si =$ which refers to the initial score before the learning process begins.

The category of improvement in students' understanding of mathematical concepts can be determined through the N-Gain score, which is used to measure the extent of improvement after participating in the learning process. The interpretation of the N-Gain value is divided into three main categories: if $g > 0.7$, the improvement is categorized as high; if $0.3 \leq g \leq 0.7$, it is categorized as moderate; and if $g < 0.3$, the improvement in student's conceptual understanding of mathematics is considered low. The teaching module based on guided discovery learning supported by Augmented Reality can be considered effective in improving students' mathematical understanding if the N-Gain value falls at least within the moderate category.

## RESULT

The product development in this study was successfully carried out using the 4D development model. The products developed include the Teaching Module, Student Worksheet, and Pre-test and Post-test questions. The teaching module was designed through the following stages.

A. Define Phase

The Define phase is the stage for identifying and describing the learning process's needs and gathering information related to the product to be developed. This phase consists of five main steps: front-end analysis, learner analysis, task analysis, concept analysis, and specifying instructional objectives.

The definition phase aims to identify the needs within the learning process and gather relevant information as a foundation for developing a teaching module on three-dimensional shapes based on guided discovery learning assisted by Augmented Reality. This phase consists of five essential components: front-end analysis, learner analysis, concept analysis, task analysis, and the formulation of instructional objectives.

The front-end analysis found that ninth-grade students at SMP Mishbahul Ulum experienced difficulties in understanding the concept of three-dimensional shapes, especially in visualizing three-dimensional forms. The learning process remains conventional and is not supported by media that can stimulate active student engagement. The worksheets are also not designed to foster deep conceptual understanding, making students less interested and having difficulty absorbing the material.

Furthermore, the analysis of student characteristics revealed that learners tend to be passive during the learning process. Group discussions were ineffective and mostly procedural. Students were not accustomed to discovering concepts independently, and learning activities were not connected to real-life contexts. The lack of visual media made it difficult for students to imagine the shapes and characteristics of solid figures, such as cubes, rectangular prisms, prisms, and pyramids. As a result, students' conceptual understanding remained low, and instruction continued to be teacher-centered. Therefore, a concept analysis was conducted to identify and systematically organize key concepts. The focus of the material includes definitions, elements, nets, surface area, and volume of three-dimensional figures. These concepts are the foundation for formulating learning objectives and expected competencies aligned with the *kurikulum Merdeka*.

Based on the concept analysis, a task analysis was conducted to guide the development of learning activities using student worksheets (LKPD). The tasks were divided into three sections: Student Worksheet 1 for cubes and rectangular prisms, Student Worksheet 2 for prisms, and Student Worksheet 3 for pyramids. Each worksheet was designed to enhance students' skills in identifying the elements of three-dimensional shapes, calculating surface area and volume, and solving contextual problems related to everyday life.

The analysis results were used to formulate learning objectives encompassing the domains of attitudes, skills, and knowledge. These objectives include student engagement during the learning process, the ability to collaborate in groups, a sense of responsibility, and the ability to comprehensively comprehend and apply the concepts of polyhedra. Based on these foundations, the development of the instructional module is expected to serve as a solution to the various challenges encountered in mathematics learning at Mishbahul Ulum Junior High School, particularly in the topic of polyhedra.

### B. Design

The Design Phase of the Teaching Module consists of four stages: (a) The development of pre-test and post-test questions. The conceptual understanding test was designed to evaluate the effectiveness of the teaching module by measuring the percentage of classical mastery and the improvement in students' mathematical conceptual understanding. The test consists of three pre-test questions and three post-test questions. (b) The selection of instructional media was based on task analysis, subject matter, student characteristics, and the availability of facilities at SMP Mishbahul Ulum Patokan Situbondo. The selected media included the teaching module, student worksheets, and the pre-test and post-test questions, designed based on guided discovery learning components supported by augmented reality using GeoGebra to enhance students' understanding of mathematical concepts. (c) The formatting of the teaching module, Student Worksheet, and pre-test and post-test covered the physical design and the content structure. These components were aligned with the structure of the *Kurikulum Merdeka*, which consists of general information, core competencies, and appendices. The format was also adjusted to fit the criteria for grade IX modules and the guided discovery learning approach supported by augmented reality (d) The initial design phase produced a prototype of the teaching module based on guided discovery learning integrated with augmented reality. The prototype included modules for three learning sessions, a student worksheet that followed the guided discovery learning stages supported by AR in GeoGebra, pre-test and post-test questions (each consisting of three essay questions) to assess students' conceptual understanding, and research instruments including a learning style questionnaire, observation sheet, student response questionnaire, and interview guide designed to evaluate the effectiveness and implementation of polyhedralearning in grade IX.

The teaching module was developed based on the guided discovery learning approach integrated with augmented reality, focusing on polyhedra for Grade IX students in Phase D. It consists of three meetings: the first discusses cubes and cuboids, the second covers prisms, and the third explores pyramids. The module is designed to support teachers in the teaching process. It includes contextual problem-solving activities, group discussions based on students' learning styles, group presentation tasks, and practice exercises in the student worksheet. The instructional sequence follows the stages of guided discovery learning assisted by GeoGebra, which include: (1) Introduction, consisting of prayer, attendance check, presentation of learning objectives, and triggering questions; (2) Stimulation, involving group division based on learning styles, distribution of student worksheet, and presentation of contextual problems; (3) Problem Statement, where students identify problems through observations in the student worksheet; (4) Data

Collection, in which students explore information and discuss using AR in GeoGebra; (5) Verification, involving the creation of works according to student's learning styles, such as videos, audio recordings, or live presentations; (6) Generalization, where the teacher provides feedback on the problem-solving results; and (7) Evaluation, where students complete practice questions in the student worksheet to assess the improvement in their conceptual understanding of mathematics.

The conceptual understanding test in this study consisted of a pre-test and a post-test, each comprising three essay questions. These questions were developed based on the indicators of competency achievement related to flat-sided three-dimensional shapes, aiming to measure students' mathematical and conceptual understanding improvement after utilizing the teaching module based on guided discovery learning supported by Augmented Reality. The test was accompanied by an answer key and scoring guidelines to ensure a more objective and structured assessment. An example of the pre-test and post-test questions is shown in Figure 1.
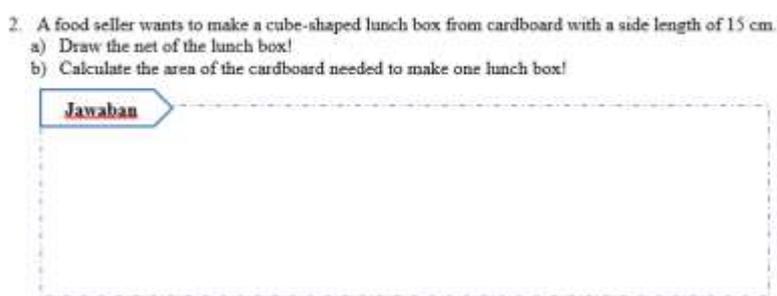


2. A food seller wants to make a cube-shaped lunch box from cardboard with a side length of 15 cm.
   a) Draw the net of the lunch box!
   b) Calculate the area of the cardboard needed to make one lunch box!

Jawaban

**Figure 1. A Question in the Final Task**

In addition, the researcher developed research instruments consisting of a learning style questionnaire, an implementation observation sheet, a student response questionnaire, and an interview guide the observation sheet covered implementing instructional stages, classroom atmosphere, and classroom management. The learning style questionnaire included 33 items using a 4-point Likert scale. In comparison, the student response questionnaire consisted of 7 items designed to gather feedback on the Guided Discovery Learning worksheets supported by Augmented Reality. The interview guide contained 10 questions for teachers and 7 questions for students, aimed at exploring their experiences and learning needs in flat-sided three-dimensional geometry in mathematics instruction.

C. Development Phase

The development phase of the teaching module, student worksheets, and final assessment tasks were validated by mathematics education experts, consisting of two university lecturers and one mathematics teacher from SMP Mishbahul Ulum. Subsequently, the validation results from these experts were analyzed using all three instruments. The results of the expert validation analysis are presented in Table 1 below.

**Table 1. Recapitulation of Instrument Validity**

| Instrument | Average Score | Criteria |
|---|---|---|
| Teaching Module | 4,47 | Valid |
| Student Worksheet | 4,30 | Valid |
| Pretest and Posttest Questions | 4,40 | Valid |

Meanwhile, the validation results for the research instruments showed that the learning style questionnaire obtained an average score of 4.56, while the student response questionnaire scored 4.29. These results indicate that the learning style questionnaire and the student response sheet developed fall into the valid category and are suitable for the study. Before the trial implementation, a readability test was conducted on the teaching module, student worksheets, and the pre-test and post-test instruments to ensure that all learning tools were comprehensible.

The readability test was conducted on six students representing visual, auditory, and kinesthetic learning styles. This test aimed to assess the extent to which the sentences and vocabulary used in the teaching module aligned with the student's learning

styles and levels of comprehension. If any errors were found, revisions would be made before the module was implemented in the field trial. This readability test was carried out after the module had been evaluated and deemed valid by the validators. The results revealed several unclear words in the student worksheets, indicating a need to simplify some sentences. Subsequently, necessary revisions were made to the student worksheets before the field trial was conducted.

The product, which had been validated, undergone a readability test, and revised accordingly, was implemented in a broader trial involving 22 students over five sessions. The implementation of the product trial is summarized in Table 2.

**Table 2. Research Schedule**

| meeting | Day and Date | Activity |
|---|---|---|
| 1 | Saturday, 9th April 2025 | Introduction, completion of learning style questionnaire, and pretest |
| 2 | Monday, 21th April 2025 | Teaching Module 1 |
| 3 | Tuesday, 22th April 2025 | Teaching Module 1 |
| 4 | Friday, 25th April 2025 | Teaching Module 1 |
| 5 | Saturday, 26th April 2025 | Posttest and completion of student response questionnaire |

In the first meeting, the researchers introduced themselves, explained the purpose of the study, distributed learning style questionnaires to 22 students, grouped them according to their learning styles (visual, auditory, and kinaesthetic), and administered a pretest consisting of three questions to measure students' initial understanding and readiness. Students were also instructed to download the GeoGebra application. In the second meeting, the learning process began with a triggering question, followed by group division based on learning styles. Students received worksheets (LKPD) and were guided to use GeoGebra to solve problems. The third meeting focused on prisms, where students participated in group discussions aligned with their learning styles and presented the results in audio, video, or live presentations. In the fourth meeting, students worked in groups on worksheets related to pyramids and presented their findings according to their learning styles. In the fifth meeting, the researcher administered a post-test to evaluate the improvement in student's conceptual understanding and the effectiveness of the teaching module. Additionally, a student response questionnaire was distributed to assess feedback and evaluate the practicality of the developed product. Data collection during the learning process utilized the Augmented Reality (AR) feature in GeoGebra, as illustrated in Figure 2.



**Figure 2. Learning Using Augmented Reality**

Furthermore, the researcher evaluated the practicality and effectiveness of the developed teaching module. The practicality of the module was assessed based on trial implementation using classroom observation sheets and student response questionnaires regarding the developed module. The results of the implementation observation can be seen in Table 3 below.

**Tabel 3. Observation Results on the Implementation of Learning Activities**

| Meeting number | Score | Category |
|---|---|---|
| 1 | 4,2 | High |
| 2 | 4,5 | High |
| 3 | 4,7 | High |
| **Average** | **4,47** | **Tinggi** |

Based on Table 3, the average result of the learning module implementation observation at each meeting was 4.47, which falls within the range of $4 \leq I_i < 5$, indicating a high category. Furthermore, an analysis was conducted on the student response questionnaire consisting of 7 questions. The results of the responses from 22 ninth-grade students at SMP Mishbahul Ulum are presented in Table 4 below.

**Tabel 4. Student Response Results**

| Question | | | | | | | Total score | Maximum score | Percentage |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | | | |
| 76 | 74 | 70 | 75 | 72 | 75 | 72 | 514 | 588 | 87% |

Based on Table 4, the percentage of students' responses to the guided discovery learning-based instruction assisted by Augmented Reality (AR) was 87%. This indicates that the developed instructional module received a positive response. Considering the implementation observation results categorized as high and the positive feedback from the student response questionnaire, it can be concluded that the developed instructional module is categorized as practical.

The next step is to analyze the effectiveness aspect. The data used to assess the instructional module's effectiveness were obtained from the students' pre-test and post-test results on conceptual understanding. Based on the post-test results of 21 students, 4 students did not achieve mastery because they scored ≤70, while 17 students achieved mastery. The classical completeness percentage reached 80.9%, which meets the criteria for classical mastery as it exceeds the minimum threshold of 70%. Meanwhile, the improvement in students' conceptual understanding based on the N-Gain analysis showed a score of 0.7, which falls into the medium category. Based on the percentage of students who met the classical mastery criteria and the N-Gain analysis results categorized as medium, it can be concluded that the developed instructional module is considered adequate.

D. Disseminate Phase

After the instructional module was declared valid, practical, and effective, it became ready to be published and distributed. The developed module, which has positively impacted students' conceptual understanding, can be disseminated through various media, such as the Internet, other schools, the Simpkb Guru Berbagi platform, and other available channels. In this study, the instructional module was disseminated at SMP Darul Falah for implementation in other classes.

## DISCUSSION

This study is a type of research and development (R&D). Creswell, as cited in Weyant (2022), explains that research and development aims to produce a specific product and test the effectiveness of that product. The development model used in this study is the Thiagarajan or the 4D model, which consists of four stages: define, design, develop, and disseminate. The researcher chose the 4D development procedure because of its systematic, precise flow and focus on validation and revision. (Weyant, 2022) He also states that the 4D model is frequently used in further development to develop instructional materials such as teaching modules, student worksheets, and textbooks.

The first stage in this development research is the define phase, which includes five main steps: initial and final analysis, student characteristics analysis, concept analysis, task analysis, and formulation of learning objectives. The analysis results indicate that mathematics learning on the topic of three-dimensional shapes in grade IX at SMP Mishbahul Ulum remains conventional, lacks visual elements, and does not align with the principles of the Merdeka Curriculum. This condition leads to low conceptual understanding, with a mastery level of only 40%. Observations and interviews also revealed that students are passive and have

difficulties visualizing three-dimensional shapes. Therefore, the researcher concludes that it is necessary to develop an innovative teaching module based on Guided Discovery Learning supported by Augmented Reality to enhance students' understanding of mathematical concepts more actively and meaningfully.

The next stage is the design phase, during which the researcher develops the instructional module for the study. The module was designed based on a Guided Discovery Learning approach supported by Augmented Reality (AR) and included supporting components such as student worksheets, pre-test and post-test questions, and other research instruments. The module was structured according to the syntax of Guided Discovery Learning, which includes the stages of stimulation, problem statement, data collection, verification, generalization, and evaluation. Meanwhile, the student worksheet contains contextual problems related to three-dimensional shapes' properties, nets, surface area, and volume. The pre-test and post-test consisted of three essay questions, each measuring the improvement of students' conceptual understanding. The supporting research instruments included a learning style questionnaire, an observation sheet for module implementation, interview guidelines, and a student response questionnaire. In the development phase, the instructional module and its components were validated by two mathematics education lecturers and one mathematics teacher. The validation scores obtained were 4.47 for the instructional module, 4.33 for the student worksheet, 4.44 for the pre-test post-test, 4.29 for the student response questionnaire, and 4.56 for the learning style questionnaire. A readability test followed these validations to ensure the clarity and accessibility of the materials.

The readability test was conducted at MTs Darul Falah Cermee Bondowoso, involving six students with different learning styles to assess the appropriateness of the module's language with the student's comprehension level. The results of this test were used to revise the student worksheet before the trial implementation. The trial of the instructional module was carried out at SMP Misbahul Ulum over five meetings. These included completing the learning style questionnaire, a pre-test, and three instructional sessions using the developed module, followed by a post-test and student response questionnaire. This implementation aimed to evaluate the module's effectiveness, feasibility, and impact on improving students' conceptual understanding of mathematics, specifically on the topic of three-dimensional solid shapes.

The practicality of the developed instructional module was analyzed through data obtained from classroom implementation observations and student response questionnaires. Based on the observation results, the implementation score reached 4.47 within the interval of $4 \leq KP < 5$, which falls into the high category. Meanwhile, the student response questionnaire analysis showed a score of 87%, indicating that the instructional module received a positive response from the students. Therefore, based on the high level of implementation and the positive student feedback, it can be concluded that the developed instructional module is practical for use in the learning process.

Next, an analysis of the instructional module's effectiveness was conducted. Effectiveness data were obtained from students' pre-test and post-test scores on conceptual understanding after using the e-module based on Guided Discovery Learning assisted by Augmented Reality (AR). The post-test results were analyzed to determine the percentage of classical learning mastery and the improvement in student's conceptual understanding. Based on the analysis, the classical mastery percentage for phase D students on the polyhedramaterial was 80.9%, which meets the criteria for classical mastery as it exceeds the minimum threshold of 70%. Meanwhile, the improvement in conceptual understanding, as analyzed using the N-Gain, showed a score of 0.7, which falls into the moderate category. Based on these two indicators, classical mastery, and the N-Gain score, the developed instructional module effectively enhances students' understanding of mathematical concepts. Sari (2024) stated that implementing Guided Discovery Learning positively improves students' understanding of mathematical concepts.

Furthermore, research conducted by Wiliyanti (2024) revealed that learning using Augmented Reality (AR) consistently enhances students' conceptual understanding and increases their interest in learning, especially in topics that are difficult to evaluate. Students demonstrated better performance compared to those taught through conventional methods. AR enables the visualization of abstract concepts in more concrete 3D forms and provides a more interactive and immersive learning experience, attracting students' attention and engagement.

Thus, the implementation of guided discovery learning assisted by Augmented Reality (AR) significantly impacts students' conceptual understanding of mathematics. This instructional module presents several advantages. First, it supports students in enhancing their comprehension of mathematical concepts and retaining information more efficiently as they better understand the methods used for independent learning and problem-solving. Second, it offers easier visualization for abstract materials, making learning more concrete and meaningful. Third, the AR-assisted guided discovery approach encourages students to develop empathy

and self-regulation while working collaboratively in groups. Fourth, the learning activities include challenging contextual problems that promote deeper mathematical conceptual understanding. However, the module has some limitations, such as the need for preparatory work before the learning process and longer time allocation for completing the Student Worksheet. Additionally, not all Android devices are compatible with the AR features in GeoGebra due to minimum system requirements, which may result in the AR not functioning correctly. Therefore, effective planning and time management are essential to ensure the successful implementation of the developed module.

## CONCLUSION

The research and development process, from the initial to the final stages, was thoroughly carried out, and it concluded that the development of the instructional module based on guided discovery learning, assisted by augmented reality, meets the criteria of being valid, practical, and effective. Furthermore, students' conceptual understanding of mathematics, particularly at SMP Mishbahul Ulum Situbondo, showed improvement through implementing this module and its accompanying Student Worksheet. This study is expected to be a reference for fostering innovative teaching practices in schools, especially in implementing the *Kurikulum Merdeka* (Independent Curriculum). Future research should expand the scope of the geometry content, explore different indicators of mathematical conceptual understanding, and involve a larger sample size. It is also recommended that future studies include media experts in the validation process of both the instructional module and the student worksheet. Based on this research's findings, using an instructional module based on Guided Discovery Learning, assisted by Augmented Reality, is recommended as an innovative alternative for geometry instruction to enhance students' conceptual understanding of three-dimensional space (solid geometry).

## REFERENCES

1. Fadilah, J. R., & Muhtadi, D. (2024). Analisis Kesulitan Siswa Dalam Menyelesaikan Luas Permukaan Dan Volume Prisma. *Koordinat Jurnal MIPA*, *5*(2), 57–68.
2. Amrina, Z., Sari, S. G., Alfino, J., & Mahdiansyah, M. (2023). Pengembangan Media Pembelajaran Matematika Berbasis Augmented Reality untuk Meningkatkan Kompetensi Mahasiswa. Jurnal Cendekia: Jurnal Pendidikan Matematika, 7(1), 380–391.
3. Artika, S. D. (2022). Penggunaan Augmented Reality Pada Aplikasi Pembelajaran Interaktif Untuk Anak. Journal of Information Technology and Computer Science.
4. Fadilah, J. R., & Muhtadi, D. (2024). Analisis Kesulitan Siswa Dalam Menyelesaikan Luas Permukaan Dan Volume Prisma. Koordinat Jurnal MIPA, 5(2), 57–68.
5. Farhana, I. (2023). Merdekakan Pikiran dengan Kurikulum Merdeka: Memahami konsep hingga penulisan praktik baik pembelajaran di kelas. Penerbit Lindan Bestari.
6. Fitria, N., Nasriadi, A., & Salmina, M. (2022). Analisis Pemahaman Konsep Geometri Terhadap Prestasi Belajar Siswa SMA Negeri 1 Unggul Darul Imarah. Jurnal Ilmiah Mahasiswa Pendidikan, 3(1).
7. Herman, H., Zalukhu, A., Hulu, D. B. T., Zebua, N. S. A., Manik, E., & Situmorang, A. S. (2023). Augmented Reality (AR) pada Geogebra Meningkatkan Kemampuan Spasial dan Pemecahan Masalah Matematis pada Materi Dimensi Tiga. Journal on Education, 5(3), 6032–6039.
8. Hosnan, M. (2014). Pendekatan saintifik dan kontekstual dalam pembelajaran abad 21: Kunci sukses implementasi kurikulum 2013. Ghalia Indonesia.
9. Husnaidi, H. (2023). Pengaruh Media Pembelajaran Augmented Reality (AR) Berbasis Android Terhadap Hasil Belajar Siswa ada Mata Pelajaran Matematika Materi Bangun Ruang. Journal of Professional Elementary Education, 2(2), 281–288.
10. Ibrokhimovich, F. J., & Mirzaxolmatovna, X. Z. (2022). The most important role of mathematics in primary school. Galaxy International Interdisciplinary Research Journal, 10(3), 652–655.
11. Imawan, O. R., & Ismail, R. (2022). Student's self-confidence change through the application of the guided discovery learning model. 5th International Conference on Current Issues in Education (ICCIE 2021), 347–351.
12. Kudsiah, M., Ahmadi, Z., & Rohini, R. (2023). Pengembangan Modul Interaktif Berbasis Augmented Reality Pada Materi Bangun Ruang Kelas V Sekolah Dasar. PEDAGOGIC: Indonesian Journal of Science Education and Technology, 2(2), 67–76.

13. Kurnia, A. N., & Hidayati, N. (2022). Analisis Kemampuan Berpikir Geometri Berdasarkan Tahap Berpikir Van Hiele pada Pembelajaran Matematika Siswa SMP. EduMatSains: Jurnal Pendidikan, Matematika Dan Sains, 6(2), 419–430.

14. Liu, G., Catacutan, D. B., Rathod, K., Swanson, K., Jin, W., Mohammed, J. C., Chiappino-Pepe, A., Syed, S. A., Fragis, M., & Rachwalski, K. (2023). Deep learning-guided discovery of an antibiotic targeting Acinetobacter baumannii. Nature Chemical Biology, 19(11), 1342–1350.

15. Madimabe, M. P., Omodan, B. I., & Tsotetsi, C. T. (2022). Incorporation of Indigenous Knowledge in the Mathematical Geometry Discipline at a TVET College. Journal of Research in Mathematics Education, 11(3), 296–312.

16. Mesra, R. (2023). Research & development dalam pendidikan.

17. Nazihah, U., Susanto, S., & Suwito, A. (2023). Penerapan Media Pembelajaran Berbantuan Geogebra untuk Memecahkan Masalah Meteri Transformasi. Griya Journal of Mathematics Education and Application, 3(3), 526–534.

18. Nugraheni, V. Y. S. T., & Mundilarto, M. (2022). Development of 2-D augmented reality integrated physics e-book to improve students' problem-solving skills. Momentum: Physics Education Journal, 6(2), 171–180.

19. Nurhasanah, A., Yuliyanti, N., Citrawati, T., Sukamto, S., Handoyo, E., & Raharjo, T. J. (2024). Implementasi Differensiasi dalam Perspektif Kontruktivisme pada Mata Pelajaran Matematika. Jurnal Edukasi Dan Sains Matematika (JES-MAT), 10(2), 115–128.

20. Nurlaela, N. (2022). Analisis Pemahaman Konsep Dan Kemampuan Pemecahan Masalah Matematika Pada Mata Kuliah Kalkulus Dasar. Jurnal Ilmiah Wahana Pendidikan, 8(19), 430–436.

21. Ojose, B. (2023). Mathematics literacy: are we able to put the mathematics we learn into everyday use? Journal of Mathematics Education.

22. Rismayanti, T. A., Anriani, N., & Sukirwan, S. (2022). Pengembangan e-modul berbantu kodular pada smartphone untuk meningkatkan kemampuan berpikir kritis matematis siswa SMP. Jurnal Cendekia: Jurnal Pendidikan Matematika, 6(1), 859–873.

23. Sari, D. (2023). Peran Teknologi Terkini dalam E-Bisnis (The Role of Latest Technology in E-Business). Available at SSRN 4568019.

24. Sari, I. N., & Sulisworo, D. (2023). Pengembangan LKPD Berbasis Augmented Reality Sebagai Media Pembelajaran Matematika. JNPM (Jurnal Nasional Pendidikan Matematika), 7(1), 1–11.

25. Saumi, F., Muliani, F., & Amalia, R. (2022). Pengembangan E-Modul Berbasis Augmented Reality Dengan Model Guided Discovery Learning Pada Materi Vektor. AKSIOMA: Jurnal Program Studi Pendidikan Matematika, 11(4), 3850–3859.

26. Siregar, A. S. W. (2022). Desain dan Validasi LKPD Berbasis Augmented Reality untuk Materi Bangun Ruang Sisi Datar dalam Meningkatkan Kemampuan Spasial Siswa Kelas VIII SMP Muhammadiyah 1 Kota Jambi. Pendidikan Matematika.

27. Siregar, T. (2023). Stages of Research and Development Model Research and Development (R&D). DIROSAT: Journal of Education, Social Sciences & Humanities, 1(4), 142–158.

28. Sugiyono, P. D. (2010). Metode Peneliian. Kuantitatif, Kualitatif, Dan R&D.

29. Susilwaty, E. (2022). Efektivitas Penggunaan Model Guided Discovery Learning Terhadap Kemampuan Pemecahan Masalah Geometri dengan Memanfaatkan Software Geogebra pada Mahasiswa STKIP Budidaya Binjai. Jurnal Serunai Matematika, 14(1), 6–14.

30. Waruwu, M., Puat, S. N., Utami, P. R., Yanti, E., & Rusydiana, M. (2025). Metode penelitian kuantitatif: Konsep, jenis, tahapan dan kelebihan. Jurnal Ilmiah Profesi Pendidikan, 10(1), 917–932.

31. Weyant, E. (2022). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches: by John W. Creswell and J. David Creswell, Los Angeles, CA: SAGE, 2018, $38.34, 304pp., ISBN: 978-1506386706. Taylor & Francis.

32. Wulandari, M., Yolviansyah, F., & Misastri, M. (2023). Team Assisted Individualization: Improving Number Competency Students' Understanding of Mathematical Concepts. Journal of Basic Education Research, 4(1), 20–30.

33. Yanuarto, W. N., & Iqbal, A. M. (2022). The The Augmented Reality Learning Media to Improve Mathematical Spatial Ability in Geometry Concept. Edumatica: Jurnal Pendidikan Matematika, 12(01), 30–40.