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DEVELOPMENT OF DISCOVERY LEARNING-BASED STUDENT WORKSHEETS TO FACILITATE MATHEMATICAL UNDERSTANDING IN GEOMETRIC TRANSFORMATION

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ABSTRACT This study addresses the issue of students' low mathematical understanding ability, which is a crucial competency in mathematics learning. In response, the research aims to develop a discovery learning-based student worksheet on the topic of geometric transformations to support meaningful learning for Grade XI high school students. The study adopts a Research and Development (R&D) approach using the ADDIE development model, consisting of the stages: analysis, design, development, implementation, and evaluation. Data were collected through interviews, observations, validation procedures, and worksheet trials. The research involved six students from Class XI-B MIPA at Al-Muslimun Senior High School during the implementation stage. Two main instruments were employed: a validation sheet to assess the validity of the worksheet and a student response questionnaire to evaluate its practicality. The results showed that the developed worksheet achieved a very valid category with an average score of 3.61 and a very practical classification in small-group trials, with an average score of 89.16. These findings indicate that the developed student worksheet meets the criteria of both validity and practicality, making it a potential alternative learning resource in mathematics education.

Keywords: student worksheet, discovery learning, geometric transformation, mathematical understanding

ABSTRAK Penelitian ini dilatarbelakangi oleh rendahnya kemampuan pemahaman matematis siswa, padahal kemampuan ini merupakan salah satu kompetensi penting dalam pembelajaran matematika. Oleh karena itu, tujuan dari penelitian ini adalah untuk mengembangkan lembar kerja peserta didik berbasis discovery learning pada materi transformasi geometri guna memfasilitasi pembelajaran siswa kelas XI. Jenis penelitian ini adalah Research and Development (R&D) dengan menggunakan model pengembangan ADDIE yang meliputi tahapan analisis, desain, pengembangan, implementasi, dan evaluasi. Teknik pengumpulan data dilakukan melalui wawancara, observasi, uji validitas, dan uji coba lembar kerja peserta didik. Subjek dalam tahap implementasi adalah enam orang siswa kelas XI-B MIPA di SMAS Al-Muslimun. Instrumen yang digunakan terdiri dari lembar validasi untuk menilai tingkat validitas dan angket respon siswa untuk menilai tingkat kepraktisan. Hasil

penelitian menunjukkan bahwa lembar kerja yang dikembangkan tergolong sangat valid dengan rata-rata skor 3,61 dan sangat praktis berdasarkan uji coba kelompok kecil dengan rata-rata skor 89,16. Dengan demikian, lembar kerja yang dihasilkan telah memenuhi kriteria valid dan praktis, serta berpotensi menjadi alternatif sumber belajar dalam pembelajaran matematika.

Kata-kata kunci: lembar kerja peserta didik, discovery learning, transformasi geometri, pemahaman matematis

INTRODUCTION

Mathematics is one of the subjects that plays a crucial role in education. In learning mathematics, students are expected to develop logical, critical, systematic, and analytical thinking skills. However, the nature of mathematics—being abstract, layered, based on conventions, axiomatic, and involving deductive reasoning—often leads students to perceive mathematics as unappealing and difficult. This is supported by Soedjadi (as cited in Ni'mah et al., 2018), who states that the abstract nature of mathematics is a primary reason students struggle to understand and apply it in their daily lives.

The importance of learning mathematics lies in its relevance to various aspects of life. Mathematics aims to develop students' conceptual understanding, the ability to relate different concepts, and the ability to apply concepts in solving problems (Ministry of Education and Culture, 2016). Given this importance, students as the next generation need to learn and master mathematics. According to Pasaribu (2017), learning mathematics helps students solve problems and enhances their potential and capabilities.

One of the essential mathematical abilities students are expected to develop is mathematical understanding. In the educational process, this ability becomes a key objective, as understanding mathematical concepts is a prerequisite for learning more advanced concepts (Simon et al., 2016). Hendriana et al. (2017) also state that mathematical understanding should be a central focus in classroom teaching to ensure meaningful learning. Similarly, Widyastuti (2015) asserts that conceptual understanding and application are key goals of mathematics education, as they go beyond memorization and require learners to understand and apply concepts in real-life contexts. A person with strong mathematical understanding can comprehend what has been learned, the steps taken, and apply concepts across different mathematical representations. This ability also supports the development of other mathematical skills such as reasoning, communication, connections, problem-solving, critical and creative thinking, and mathematical representation (Hendriana et al., 2017). Therefore, integrating mathematical understanding into classroom practice is crucial.

In practice, however, students' mathematical understanding remains relatively low. Rahmawati and Roesdiana (2022) found that students in one Grade 12 science class

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demonstrated low levels of understanding. Among three indicators of mathematical understanding based on the Miles and Huberman model, some students had difficulty classifying objects based on concepts. Supporting this, Andelia et al. (2022) found that 85% of students struggled to understand geometric transformation concepts, especially when applying them in real-life contexts. Fitri Indah (as cited in Maulani et al., 2020) also highlights geometric transformation as a topic that students find particularly difficult.

Geometric transformation is a geometry topic involving changes in size and position and is commonly represented through matrices and visual images (Istiqomah, 2020). The subtopics include translation, reflection, rotation, dilation, and transformation composition. This topic is significant because: (1) it connects to real-world contexts; (2) it allows students to reflect on the meaning of mathematical concepts; and (3) it enables engagement in higher-order thinking through various forms of representation tailored to students (Hollebrands, as cited in Pramana et al., 2022). However, each subtopic presents its own level of difficulty, and limitations in learning tools further hinder students' ability to represent geometric ideas (Sariyasa, 2017).

Improving students' mathematical understanding requires attention to the learning process. Degeng (as cited in Aisyah, 2022) emphasizes that improving student outcomes can be achieved by enhancing instructional quality, especially by focusing on conceptual understanding. One appropriate model for this is Discovery Learning, which is a student-centered approach aligned with the 2013 curriculum. MoEC (2014) describes discovery learning as similar to inquiry-based learning, but while inquiry involves authentic problem-solving, discovery learning focuses on guiding students to uncover principles and concepts. In this model, students are encouraged to use their thinking skills to formulate discoveries through investigation (Bakar et al., 2020), rather than merely taking notes and memorizing material.

For discovery learning to be implemented effectively, innovative and creative instructional materials are essential, such as student worksheets. Prastowo (as cited in Aisyah, 2022) describes student worksheets as instructional materials containing tasks, instructions, and steps for students to complete both theoretically and practically. Challenges faced by teachers in developing these materials include low motivation to create them, difficulties in designing effective worksheets, and a tendency to produce worksheets that only contain formulas, summaries, examples, and similar exercises—resulting in limited conceptual understanding (Pulungan et al., 2020; Atika & Zulkardi, 2016).

Interviews with mathematics teachers at SMAN 1 Tambang and SMAS Al-Muslimun indicate that students' mathematical understanding remains low, partly because teachers rely heavily on textbooks and pre-prepared notes. These materials are difficult for students to comprehend, and although some contain activities intended

to help with understanding, many students are confused by them and prefer materials that are easier to interpret directly.

Wulandari et al. (2019) observed that teaching practices often involve students reading from textbooks and listening to the teacher explain sample problems. This routine discourages students from engaging deeply with the concepts. As a result, they struggle when asked to restate concepts or apply them to different types of problems. Yet, both restating and applying concepts are key indicators of mathematical understanding (Hendriana et al., 2017).

Improving learning outcomes can be pursued by developing well-designed student worksheets that align with curriculum goals, learning targets, and appropriate instructional strategies. The 2013 Curriculum and MoEC Regulation No. 22 of 2016 emphasize that instructional tools should be developed according to the adopted model and strategies. Several studies, such as those by Jainuri et al. (2021) and Fitriani (2021), have developed discovery learning-based worksheets, but none have specifically targeted geometric transformations.

Based on the challenges and research gaps described above, there is a need to develop student worksheets based on discovery learning to support the mathematics learning process. These worksheets are expected to facilitate students' learning outcomes. Therefore, the objective of this research is to develop discovery learning-based student worksheets on geometric transformation that meet the criteria of validity and practicality.

METHODS

This study employed a Research and Development (R&D) approach, following the ADDIE development model, which consists of five stages: analysis, design, development, implementation, and evaluation (Tegeh & Kirna, 2013). Each stage was carried out as follows:

The analysis stage aimed to identify the necessity of developing a student worksheet and determine the requirements needed for its development. In this phase, problems related to students' understanding of geometric transformations and current instructional tools were identified through observations and preliminary studies. The design stage focused on preparing an initial draft of the student worksheet. This involved determining product specifications, which included both pedagogical aspects—such as the selected learning model (discovery learning)—and non-pedagogical aspects, such as interface and layout design. The instructional objectives, learning flow, and supporting materials were also constructed during this stage.

In the development stage, the initial draft of the worksheet was refined through a validation and revision process. This stage involved two main activities: validation by experts and one-on-one testing with students. Expert validators assessed the worksheet for content accuracy, pedagogical quality, and visual appeal. Revisions

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were made based on feedback provided. The implementation stage involved applying the developed worksheet to students in a real classroom setting. This was done to evaluate its practicality and effectiveness. Observations and student feedback were collected to assess how well the worksheet supported the learning process. Lastly, the evaluation stage aimed to measure whether the objectives of the worksheet development were achieved. A summative evaluation was conducted by analyzing the results of student responses and performance after using the worksheet.

The trial phase of the research involved six students from Grade XI-B MIPA at Al-Muslimun Senior High School. The research utilized both qualitative and quantitative data. Qualitative data were obtained from expert validators in the form of suggestions and comments during the validation phase. Quantitative data consisted of the validity and practicality scores of the student worksheet, based on validator assessments and student responses.

To collect the data, several instruments were used: a validation sheet for assessing the validity of the student worksheet, and a student response questionnaire to assess practicality. Data collection techniques included interviews, observations, validation testing, and small-scale trials. The data were analyzed using a validity analysis technique interpreted according to Arikunto (2012), and a practicality analysis interpreted using the guidelines provided by Akbar (2017).

FINDING AND DISCUSSION

This research found a set of discovery learning-based student worksheets on the topic of geometric transformations that can facilitate student learning outcomes. The development process follows the ADDIE model, which is outlined as follows.

Analysis

The analysis activities carried out are divided into three parts: needs analysis, student analysis, and curriculum analysis. In the needs analysis, the fundamental problems in the implementation of learning using the 2013 curriculum and their solutions are established. From the results of the interview with the mathematics teacher, it was found that, in general, teachers use the 2013 curriculum mathematics textbook, revised edition 2017, as a learning resource. The teacher said that the book is not owned by all the students. Therefore, the solution is to provide discovery learning-based student worksheets that emphasize understanding concepts through active knowledge search by students through discovery, encouraging them to independently seek problem-solving and the accompanying knowledge, resulting in truly meaningful knowledge.

The second activity is student analysis. The developed student worksheet is intended for high school students in grade XI, who typically fall within the age range of 15 to 18 years. According to Piaget (in Ramdani, 2014), at that age, individuals already

possess the ability to reason, think abstractly, and draw conclusions. From the analysis of students obtained through interviews and observations, it was found that eleventh-grade students have difficulty understanding the material on geometric transformations due to their low comprehension skills. This was evidenced when the students worked on the problems; they struggled to come up with solutions. In addition, the teaching and learning activities in the classroom are not yet student-centered. When the teacher is teaching, some students seem not to pay attention and only a few are willing to respond to the teacher. During the teaching and learning activities in the classroom, student-centered learning is needed so that the learning becomes meaningful. One way that can be pursued is to utilize the discovery learning model.

The final activity in the analysis stage is curriculum analysis. The material set is geometric transformations for eleventh grade based on the 2013 curriculum. The basic competencies in this research are based on the Minister of Education and Culture Regulation Number 37 of 2018, which includes 3.5 "Analyzing and comparing transformations and compositions of transformations using matrices" and 4.5 "Solving problems related to geometric transformation matrices (translation, reflection, dilation, and rotation)." From these competencies, indicators of competency achievement and sub-materials of geometric transformations are designed, divided into five, covering translation, reflection, rotation, dilation, and composition of transformations.

Design

The first activity in the design stage is to gather references related to the material of geometric transformations. The collection of references through relevant sources, namely the e-book titled *"Mathematics for Senior High School/MA/SMK/MAK Class XI Semester 1"* from the 2013 curriculum, 2018 edition published by the Ministry of Education and Culture, and the e-module titled *"General Mathematics Learning Module for Senior High School Class XI KD 3.5"* from the Ministry of Education and Culture.

The second activity is determining the layout of the student worksheet. The cover page includes the title of the worksheet, the material, student identity, the learning objectives for each worksheet, and instructions for completing it. The table of contents contains the steps of learning that align with the discovery learning model, starting with presenting a stimulus in the form of realistic problems related to the material of geometric transformations. Then it continued with activities to identify problems, collect data, process data, verify data, and draw conclusions. (See Figure 2)

The last part of the student worksheet content is a sheet of questions to train students' mathematical understanding skills independently. (See Figure 3)

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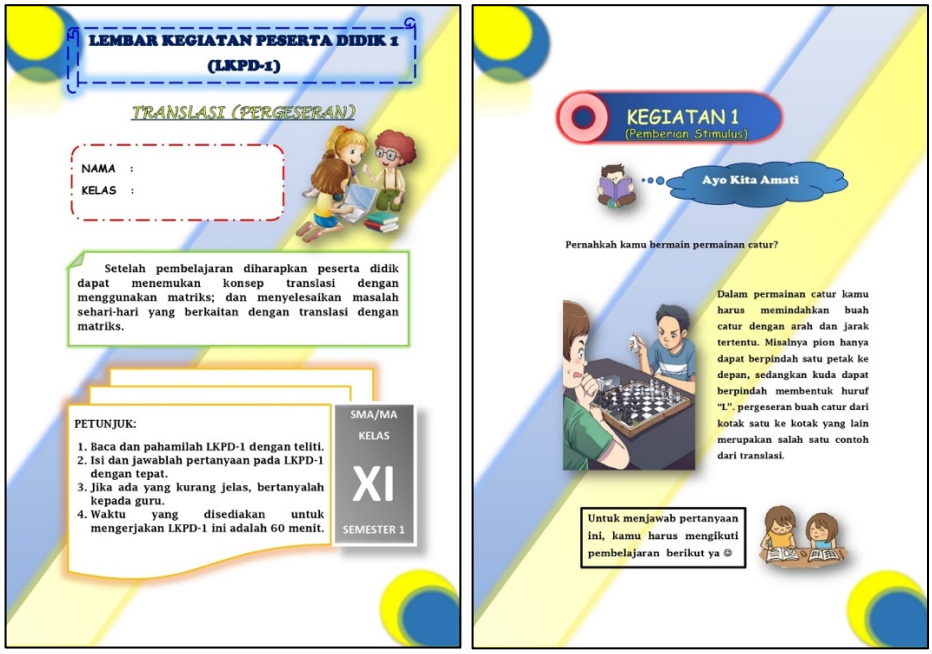

Figure 2. Design Display of the Student Worksheet

The next activity is to create prototype-1 of the student worksheet based on the layout that has been established previously. The student worksheet created is in the form of printed media. The final activity is to design the validation sheet for the student worksheet and a questionnaire for students regarding the practicality of the worksheet. Both data collection instruments were filled out using a Likert scale with 4 response options.

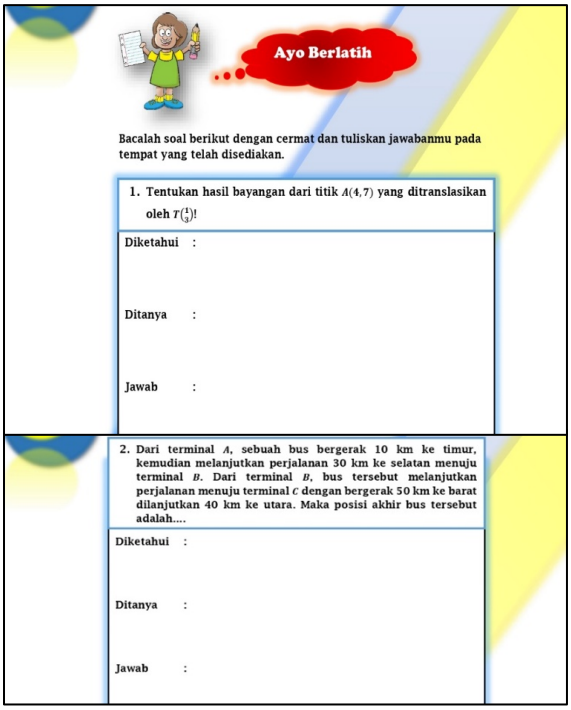

Figure 3. Example of Mathematical Understanding Questions in the Student Worksheet

Development

The first stage after creating prototype-1 of the student worksheet is the validation, which is useful for determining the quality and suitability of the student worksheet for use in schools.

Table 1. Summary of Validity Analysis Data for Student Worksheet

Aspects being evaluated	Average Assessment of the LKPD					Average	Category
	I	II	III	IV	V		
Components of the Student Worksheet	4	4	4	4	4	4	Very Valid
Relevance of Learning Materials	3,67	3,58	3,67	3,67	3,67	3,65	Very Valid
Alignment of Worksheet Activities with Discovery Learning Steps	3,4	3,61	3,67	3,67	3,67	3,60	Very Valid
Alignment of Worksheet Activities with Mathematical Understanding Indicators	3,3	3,3	3,3	3,3	3,3	3,3	Very Valid
Compliance with Didactic Requirements	3,3	3,50	3,50	3,50	3,50	3,46	Very Valid
Compliance with Construction Requirements	3,53	3,53	3,60	3,67	3,73	3,61	Very Valid
Compliance with Technical Requirements	3,58	3,67	3,58	3,67	3,67	3,63	Very Valid
Overall Average	3,54	3,60	3,62	3,64	3,65	3,61	Very Valid

The aspect that received the highest average is the "student worksheet components" with a perfect score in all five worksheets, which is 4, categorized as very valid. Meanwhile, the aspect of "Alignment of student worksheet activities with mathematical understanding indicators" received the lowest average at 3.3, but it is still considered very valid. Overall, the worksheet is classified as very valid with an average score of 3.61 for each assessment aspect across the five worksheets. This aligns with Arikunto (2012), who states that a validation score within the range of 3.26 – 4 falls under the very valid criteria.

The revisions obtained from the validator's suggestions for improving this student worksheet include:

Replacing the image on worksheet-1 with an image suitable for grade XI students and providing a caption, as well as including command words in each activity;

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Writing the learning objectives on the cover page;

Providing an explanation of the alignment of student worksheet activities with mathematical understanding indicators, as their alignment has not yet been evident.

Next, a one-on-one trial will be conducted to assess the readability of the student worksheet involving three eleventh-grade high school students. At this stage, the students will work on the worksheet and be interviewed to gather corrections and feedback, which will serve as a reference for revising the worksheet. The improvements made will focus on correcting inappropriate wording.

Implementation

Once the student worksheet has been validated and revised, it will then be tested on a small group of students, specifically 6 students from grade XI of SMAS Al-Muslimun. The purpose of the testing activity is to determine the level of practicality of using the worksheet. Before working on the worksheet, students are given a brief explanation regarding the filling instructions. During the process of working on the worksheet, the researcher acts as a facilitator. In addition, observations were made on the activities and responses of the students while working on the worksheet, and the results found that initially they were still confused and asked many questions. However, after understanding the procedure for completing the worksheet, it was evident that the majority of students were interested, happy, and actively engaged in the activities within the worksheet. Once the students finished filling out the worksheet, they were also asked to complete a student response questionnaire and provide comments in that questionnaire regarding the use of the worksheet.

Evaluation

In the evaluation stage, a practical analysis of the worksheet was conducted through the student response questionnaire, with the results presented in Table 2.

Table 2. Recap of Data on the Practicality Analysis of the Student Worksheet (Small Group)

Aspects being evaluated	Average Assessment of the LKPD					Average	Category
	I	II	III	IV	V		
Components of the Student Worksheet	4	4	4	4	4	4	Very Valid
Relevance of Learning Materials	3,67	3,58	3,67	3,67	3,67	3,65	Very Valid
Alignment of Worksheet Procedures with Discovery Learning Model	3,4	3,61	3,67	3,67	3,67	3,60	Very Valid
Alignment of Worksheet Activities	3,3	3,3	3,3	3,3	3,3	3,3	Very Valid

Aspects being evaluated	Average Assessment of the LKPD					Average	Category
	I	II	III	IV	V		
with Mathematical Understanding Indicators							
Compliance with Didactic Requirements	3,3	3,50	3,50	3,50	3,50	3,46	Very Valid
Compliance with Construction Requirements	3,53	3,53	3,60	3,67	3,73	3,61	Very Valid
Compliance with Technical Requirements	3,58	3,67	3,58	3,67	3,67	3,63	Very Valid
Overall Average	3,54	3,60	3,62	3,64	3,65	3,61	Very Valid

The average assessment of the practicality of the student worksheet overall is 89.16, which is classified as very practical. These results are in line with Akbar (2017), who states that a product is considered very practical when its practicality score is in the range of 85.01% – 100%. This is also supported by Fitri et al. (2020), who assert that student worksheets can be classified as very practical when the average score exceeds 81%.

Based on the findings of this research, it can be concluded that the developed student worksheet meets the requirements of being valid and practical. The results of this study align with previous research, such as Jainuri et al. (2021) and Fitriani (2021), which developed valid and practical worksheets using the discovery learning model; however, neither of these studies referenced the topic of geometric transformations.

The development process carried out in this research only reached small group testing as the final product, so it is recommended for future researchers to conduct studies up to large group testing, as according to Tessmer (in Ambiyar, 2018), large group testing is useful for evaluating the effectiveness of a product.

CONCLUSIONS AND RECOMMENDATIONS

Based on the findings of this research, it can be concluded that the discovery learning-based student worksheet on the topic of geometric transformation—designed to support students' conceptual understanding—has met the criteria of being both valid and practical. This student worksheet, which was developed for use in the mathematics curriculum for Grade XI students at the senior high school or Madrasah Aliyah level, was validated by experts and tested in a small group trial. The

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validation results indicate that the content, structure, and instructional design of the student worksheet are highly appropriate. Furthermore, student responses demonstrated that the worksheet is practical and supports active, meaningful learning through discovery-based activities.

Therefore, the developed student worksheet is recommended as an alternative learning resource that can be used by both teachers and students to enhance mathematical understanding in geometry, particularly in the topic of geometric transformations. The design of the worksheet aligns with the 2013 curriculum; however, considering recent policy shifts, it is suggested that future studies adapt the structure and content to be compatible with the Merdeka Curriculum.

Additionally, future researchers are encouraged to extend the development process beyond small group trials by conducting large-scale practicality tests and effectiveness evaluations. These further steps are necessary to ensure that the worksheet not only meets the criteria of validity and practicality but also significantly improves student learning outcomes across diverse classroom settings.

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