Available online at http://journal.uny.ac.id/index.php/jrpm

Jurnal Riset Pendidikan Matematika 12 (1), 2025, 100–120

Developing Inductive Approach-Based Worksheets for Enhancing Students' Mathematical Generalization Skills

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ARTICLE INFO

Article history
Received: 16 Feb 2025
Revised: 21 Mar 2025
Accepted: 24 Mar 2025

Kata Kunci:
Kemampuan Generalisasi;
Pendekatan Induktif;
Penelitian Pengembangan;
Lembar Kerja Siswa

Keywords:
Generalization Skills;
Inductive Approach;
Development Research;
Student Worksheets

ABSTRACT

Di abad ke-21, kemampuan untuk menggeneralisasi konsep matematika sangat penting bagi perkembangan kognitif siswa. Namun, bahan ajar yang tidak mendukung pengembangan kemampuan ini dapat menghambat hasil belajar siswa. Oleh karena itu, guru membutuhkan bahan ajar yang efektif yang dapat meningkatkan kemampuan siswa dalam menggeneralisasi. Penelitian ini bertujuan untuk mengembangkan bahan ajar berbasis pendekatan induktif untuk meningkatkan kemampuan generalisasi matematis siswa. Penelitian ini menggunakan model ADDIE, yang terdiri dari lima tahap yaitu analisis, desain, pengembangan, implementasi, dan evaluasi. Penelitian ini menggunakan lembar kerja siswa yang telah divalidasi oleh ahli materi dan ahli media. Selain itu, pre-test dan post-test dilakukan untuk menilai keefektifan dan kepraktisan lembar kerja siswa (LKS). Hasil penelitian menunjukkan bahwa lembar kerja siswa yang dikembangkan memenuhi kriteria kevalidan, kepraktisan, dan keefektifan. Kevalidan LKS diperoleh melalui penilaian positif dari dua ahli materi dan dua ahli media. Kepraktisan ditentukan berdasarkan umpan balik positif secara keseluruhan dari siswa. Terakhir, keefektifan LKS ditunjukkan dengan adanya peningkatan yang signifikan pada kemampuan generalisasi matematis siswa setelah intervensi.

In the 21st century, the ability to generalize mathematical concepts is crucial for students' cognitive development. However, teaching materials that fail to support the development of this skill can hinder student learning outcomes. Therefore, educators need effective teaching materials that improve students' ability to generalise. This study aims to develop teaching materials based on an inductive approach to improve students' mathematical generalization skills. This research uses the ADDIE model, which consists of five phases: analysis, design, development, implementation and evaluation. The study used student worksheets that had been validated by subject and media experts. In addition, pre- and post-tests were conducted to assess the effectiveness and practicality of the worksheets. The results indicated that the developed student worksheets met the criteria for validity, practicality, and effectiveness. The validity of the worksheets was confirmed through positive evaluations from two material experts and two media experts. Practicality was determined based on the overall positive feedback from students. Finally, the effectiveness of the worksheets was demonstrated by a significant improvement in students' mathematical generalization skills following the intervention.

How to Cite: Nirfayanti, Ernawati, & Wijaya, T. T. (2025). Developing inductive approach-based worksheets for enhancing students' mathematical generalization skills. *Jurnal Riset Pendidikan Matematika*, *12*(1), 100–120. https://doi.org/10.21831/jrpm.v12i1.83409

INTRODUCTION

Generalization is a crucial skill in mathematics education. It's a fundamental way of thinking and communicating, forming the bedrock of mathematical understanding (Naraswari et al., 2023). Generalization lies at the heart of all key mathematical activities. Generalization is highlighted as crucial in both the established curriculum standards and the body of study dedicated to mathematics teaching (Dinarti, 2022; Iswara et al., 2022; Saefurohman et al., 2023). Generalization is fundamental in mathematics, particularly when seeking universal formulas. Students contribute to this process by recognizing patterns and extrapolating these patterns to formulate subsequent formulas (Sosa Moguel et al., 2019). Generalization lies at the heart of mathematical endeavors, facilitating the development of novel insights (Naraswari et al., 2023). Moreover, it is indispensable for comprehending diverse mathematical ideas, and proficiency in generalization constitutes a cornerstone of effective mathematics education (Callejo & Zapatera, 2017; Hayuningrat & Rosnawati, 2022; Karabulut & Ozmen, 2019). Thus, the ability to generalise from a variety of mathematical problems is an important basic skill for students and apply them to different situations.

One approach that effectively supports this generalization process is the inductive approach, where students move from specific observations to broader generalizations, thus strengthening their ability to recognize and apply mathematical patterns. This approach focuses on data collection, patterns of observation, and results that can be used to form a more general concept or theory. According to Brown & Walter (2005), the inductive approach in mathematics education emphasizes active interaction between students and learning materials, where through observation and experimentation, they independently find patterns, identify them, formulate hypotheses, and finally make generalizations.

At the initial stage, students are given some examples or special cases related to a mathematical concept. For example, the teacher can introduce a series of even numbers (2, 4, 6, 8, etc.) and ask students to observe the characteristics of these numbers. After giving examples, students should be encouraged to find patterns or relationships. In the case of even numbers, students might realize that all of these numbers can be divided by 2 without a remainder. Based on the patterns identified, students are encouraged to form hypotheses about the characteristics of even numbers in general, for example, "All even numbers are the product of 2k, where k is a whole number. In the final stage, students are expected to apply the patterns and hypotheses in a broader context. For example, they can apply their understanding of even numbers in other mathematical operations or in solving everyday problems.

Generalization prompts students to identify principles applicable across diverse scenarios (Shuriye & Daoud, 2011). Neglecting the cultivation of generalization skills hinders the development of robust mathematical reasoning (Mujizatullah, 2018). Generalization ability also allows students to try to find the general characteristics of a problem as well as the general solution to the problem in question (Ramdhani et al., 2019). The generalization abilities of students affect their mathematical thinking ability (Weinberg, 2019). Generalization is a fundamental component of mathematical thought. By employing generalization, students can enhance their comprehension of key mathematical concepts (Aprilita et al., 2016). The inductive approach aligns with this by engaging students in a structured process of pattern recognition, fostering a deeper conceptual understanding rather than rote memorization (Bruner, 1961; Harel & Tall, 1991). Generalization is the process of drawing a conclusion in the form of the essence or main idea of the learning process that has been learned towards a general conclusion (Anggoro, 2016; Nirfayanti & Syamsuriyawati, 2024). So that this conclusion is drawn after students have gone through all the series of processes of solving or finding solutions to problems.

However, generalisability-oriented learning is still lacking, according to the facts on the ground. Indonesia's performance in mathematics, as reflected in the 2022 PISA results, underscores the need for improved instructional strategies. Ranked 66th out of 81 countries, Indonesia's mathematics score fell significantly below the international average, indicating persistent challenges in mathematical reasoning and problem-solving (OECD, 2023). Apart from this, the learning used by teachers in secondary schools pays less attention to student abilities. There are several reasons for the low generalisation ability, including because students find it difficult to make connections between concepts, they do not understand the problems in the problem and student activeness tends to be weak (Yusepa, 2017). Previous research has also shown that many students are only able to memorize formulas without understanding their applications in a broader context (Hamzah et al., 2021). The low ability of students to generalize mathematical concepts is also due to the fact that teachers still use conventional teaching

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

methods, with classrooms remaining teacher-centered as the sole source of learning (Anggoro, 2016; Yuni, 2011). Implementing an inductive approach in mathematics learning can address these issues by promoting student engagement and facilitating deeper conceptual understanding through structured exploration (Polya, 1945; Zazkis & Liljedahl, 2002). Thus, the capability for mathematical generalization is imperative for the improvement and advancement of students within the context of mathematics education.

Recognising the importance of developing mathematical generalization skills, there is a need for mathematics learning that involves more active student participation and involvement in the learning process. One approach that can be used to overcome this problem is the inductive approach, where students are invited to discover concepts or principles through observation and analysis of specific examples before drawing general conclusions. Inductive learning requires active students where during the learning process students make several observations to build a number of concepts or generalisations, while the teacher acts as a facilitator to guide and direct (Fitrianna et al., 2021). Previous research has shown that the application of an inductive approach in mathematics learning can improve students' mathematical representation ability, which is an important component in the mathematical generalisation process (Puspandari et al., 2019). The same finding was revealed in studies conducted by Aisyah (2016) and Nurlinda & Nirfayanti (2022), which showed that the inductive approach can enhance students' ability to generalize and improve their learning outcomes. Through qualitative analysis, it was found that inductive reasoning is used by teachers to help students understand mathematical concepts by moving from specific cases to generalization (Rochmad, 2007).

The development of teaching materials based on the inductive approach is relevant in this context, because teaching materials designed with this approach can facilitate a more effective learning process. Such teaching materials can help students develop critical and analytical thinking skills, which are needed to make mathematical generalisations. The materials provided e-books, modules and student worksheets make the inductive learning approach suitable for secondary school students (Fitrianna et al., 2021; Iliana et al., 2023; Puspandari et al., 2019). Learners do not experience difficulties with teaching materials with an inductive learning approach. Therefore, inductive learning may be the best choice to help students improve their generalisation skills with the help of teaching materials.

Teaching materials encompass all resources utilized by educators to facilitate the instructional process (De Jong et al., 2019). Student worksheets constitute a key example of such materials within the educational context. These worksheets serve as valuable tools for guiding learners in comprehending procedural skills and fundamental concepts (Dewi et al., 2023; Nurfadhillah et al., 2018). Research by Khairiyah et al. (2019) indicates that the use of student worksheets based on the inductive approach can enhance students' critical thinking skills. E-books based on inductive learning can improve students' reasoning skills and are feasible to use and fall into the good category (Fitrianna et al., 2021).

Various studies examining the development of student worksheets have been conducted. Some studies were conducted in Yogyakarta (Hayuningrat & Rosnawati, 2022), South Sulawesi (Baharuddin et al., 2024), North Sumatra (Lubis, 2023), and West Kalimantan (Iryani et al., 2023). Most of these studies were conducted in junior high schools (Baharuddin et al., 2024; Iryani et al., 2023; Lubis, 2023). Some other studies involved a realistic approach to improve students' mathematical generalisation ability (Hayuningrat & Rosnawati, 2022). On the other hand, some previous studies have developed learning tools with an inductive approach for the material of linear equations of one variable (Puspandari et al., 2019), and social arithmetic (Fitrianna et al., 2021), but research on the development of student worksheets with an inductive approach to the material of flat-sided space building does not exist. However, no research has developed student worksheets based on an inductive approach to improve mathematical generalisation ability. In this research, student worksheets are presented as a medium in learning that involves students' thinking patterns from observing specific examples to then drawing general conclusions or basic principles. For this reason, we developed instructional resources designed as student worksheets utilizing an inductive learning approach to enhance students' mathematical generalization skill in the topic flat-sided space building material.

Thus, this research not only contributes to the development of theory in mathematics education, but also provides practical solutions for teachers in improving students' mathematical generalisation skills through effective teaching materials. The results of this study are expected to serve as a reference for the development of similar teaching materials in the future.

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

METHOD

This study aims to develop student worksheets that meet the criteria of validity, practicality, and effectiveness by implementing a research and development approach based on the ADDIE model. This model consists of five systematic stages: analysis, design, development, implementation, and evaluation (Branch, 2009).

The development procedure in this study is the first stage of analysis. This stage aims to obtain relevant information related to the development of flat-sided space building materials as part of the preparation for the development of teaching materials. This analysis includes curriculum analysis, material analysis, analysis of student characteristics and lesson planning to find existing problems related to flat-sided spaces. Data was collected through teacher interviews, student questionnaires, and document analysis.

The second stage is the product design stage. At this stage the researchers tried to compile inductive approach-based learner worksheets oriented to students' mathematical generalization ability. The devices developed include learner worksheets and generalization ability test questions. Learner Worksheets developed are focused on flat-sided space building material, including cubes, beams, prisms and pyramids.

The third stage is the development stage. The draft product that has been produced is then validated by experts, namely material experts and media experts. Material experts and media experts are conducted to test the validity of the product in the form of worksheets based on an inductive approach. Material experts assess the suitability of the material, accuracy of concepts, and integration with the curriculum. While media experts evaluate readability, appearance design, and feasibility of visual presentation. Feedback sought includes material errors, readability, visual appeal, and suitability for student characteristics. The validation results were used as the basis for evaluating and revising the initial draft of the device before it was tested. If the material experts and media experts state that the product that has been made is suitable for testing in the field, the researcher then continues to test the product.

The fourth stage is the implementation stage. Products that have been declared feasible by material experts and media experts are tested. The trial was conducted in two stages, namely small-scale trials and large-scale trials. The small-scale trial involved 30 students from Class VII.E to observe their initial response to the developed student worksheet. After that, a large-scale trial was conducted involving 31 students from Class VIII.B to evaluate the effectiveness of the student worksheet more broadly. The effectiveness measurement was carried out through a pretest to determine the initial ability of students before learning using the student worksheet, as well as a posttest after the learning was completed to assess the improvement of their mathematical generalization ability. In addition, observations and questionnaires were conducted to assess the practicality of the student worksheet based on student involvement during learning. The trial results were then used as the basis for product evaluation and improvement so that the final product was produced. During this process, the researcher plays an active role in guiding students in using the worksheets to measure their effectiveness in enhancing mathematical generalization skills (Cahyadi, 2019; Fadhila et al., 2022).

The last stage is the evaluation stage. This stage aims to examine and analyse the extent to which the student worksheets meet the criteria of validity, practicality, and effectiveness in the learning process. This evaluation is conducted after implementation to identify the strengths and weaknesses of the developed teaching materials. If necessary, revisions are made to enhance the impact of the student worksheets in achieving learning objectives. The evaluation process is crucial in ensuring that the developed worksheets systematically and continuously improve the quality of learning (Cahyadi, 2019; Puspandari et al., 2019). An illustration of the research process using the ADDIE model is presented in Figure 1.

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

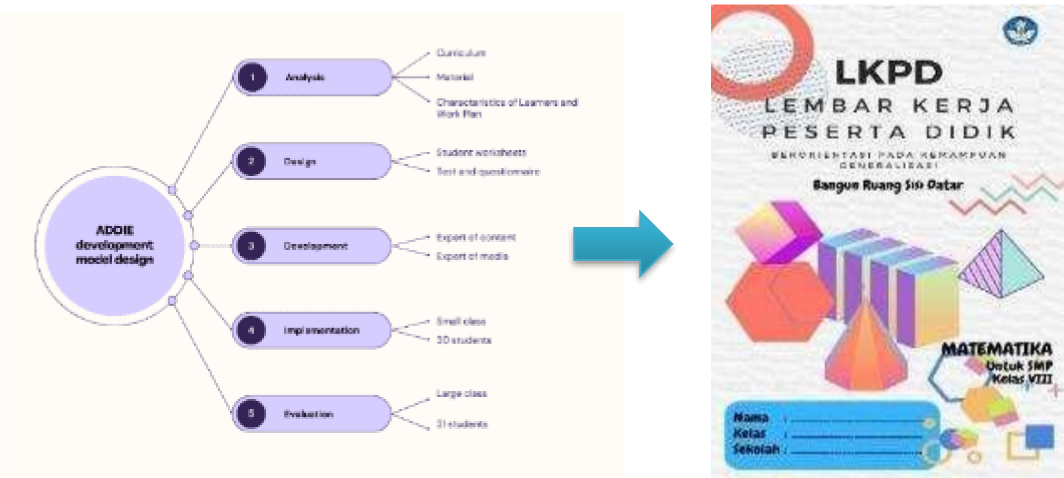


Figure 1. Research process using ADDIE design

The data analysis technique in this study was carried out by converting the quantitative data obtained into five-scale qualitative data with reference to the formula adapted from (Mudhakir et al., 2023) which is presented in Table 1.

Table 1. Student worksheet validity criteria

Score	Criteria
$3,5 \leq V_r \leq 4,0$	Very Valid
$2,5 \leq V_r < 3,5$	Valid
$1,5 \leq V_r < 2,5$	Not Valid
$1,0 \leq V_r < 1,5$	Very Invalid

Worksheets are said to be valid if the results of the expert assessment reach the minimum valid category.

The practicality test of the student worksheet was obtained from the students' response questionnaire. The questionnaire distribution was carried out after the implementation stage of the student worksheet in learning. The student worksheet practicality test is calculated using the following formula:

$$P = \frac{\sum X}{N} \times 100\%$$

Description:
P = Percentage score
$\sum X$ = Number of scores obtained
N = Maximum score
The results of the student worksheet practicality test calculation are converted into qualitative criteria with guidelines as presented in Table 2 below: (Hidayat & Irawan, 2017).

Table 2. Criteria for assessing the practicality of student worksheets

Score	Criteria
81% - 100%	Very Practical
61% - 80%	Practical
41% - 60%	Quite Practical
21% - 60%	Less Practical
0% - 20%	Very Less Practical

Worksheets are said to be practical if the results of student responses reach a minimum practical category.

Student worksheet effectiveness test is obtained from the test results of students. The test was conducted after carrying out learning using student worksheet. The test results of students are declared complete if the scores obtained at least meet the Minimum Completeness Criteria set by the school. The Minimum Completeness Criteria for mathematics lessons set by the school is 75. While the percentage of completeness of learning outcomes is calculated using the following formula:

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

$$\bar{X} = \frac{L}{N} \times 100\%$$

Description:
L = Number of students who are complete
N = Number of all students
The percentage of completeness obtained is converted into the criteria for the effectiveness of the student worksheet as presented in Table 3 below: (Irsalina & Dwiningsih, 2018)

Table 3. Criteria for testing the effectiveness of student worksheet

Score	Criteria
$\bar{X} \geq 85\%$	Very Effective
$75\% \leq \bar{X} < 85\%$	Effective
$60\% \leq \bar{X} < 75\%$	Quite Effective
$50\% \leq \bar{X} < 60\%$	Not Effective
$\bar{X} < 50\%$	Very Ineffective

Student worksheets are said to be effective if the percentage of students' mathematical generalization ability tests classically at least meets the effective category.

RESULTS AND DISCUSSION

3.1. Phase of Analysis

The analysis phase constitutes the foundational step preceding the design of instructional materials. This phase encompasses a comprehensive examination of the curriculum, learner characteristics, existing materials, and the projected work plan, ensuring that the developed teaching materials effectively address the specific needs and circumstances of the learning environment.

3.1.1. Curriculum Analysis

Interviews with teachers regarding the implementation of the curriculum in this school were conducted before evaluating the mathematics curriculum in use. The interview results revealed that two curricula are currently being implemented: the 2013 Curriculum and the Merdeka Curriculum. Additionally, this study examines how the topic of three-dimensional shapes with flat surfaces is taught in the 2013 Curriculum for eighth-grade students. The analysis includes an assessment of how this material is integrated with the Core Competencies and Basic Competencies as outlined in the curriculum.

In practice, teachers utilize the knowledge and skills specified in the Core Competencies and Basic Competencies of the 2013 Curriculum as guidelines for instruction. However, the full implementation of the curriculum remains challenging, particularly due to the absence of systematically developed Competency Achievement Indicators (CAIs) by teachers. According to the interview findings, CAIs are generally developed based on the Basic Competencies, which are fully incorporated into the curriculum.

The 2013 Curriculum and Merdeka Curriculum have fundamental differences in the learning approach, competency structure, and flexibility in teaching flat-sided space building material. In terms of learning approaches, Curriculum 2013 applies a competency-based approach that emphasizes conceptual understanding through the stages of observing, questioning, trying, reasoning, and communicating. Learning in this curriculum is more structured with reference to the Core Competencies and Basic Competencies that have been determined nationally. In contrast, the Merdeka Curriculum provides greater flexibility to teachers in designing learning according to student needs. The approach used in this curriculum is more project-centered and in-depth exploration of concepts, allowing students to be more active in understanding and applying the material according to the context that is relevant to them.

In terms of competency structure and achievement indicators, the 2013 Curriculum describes flat-sided space building material explicitly in Basic Competencies, with indicators of competency achievement that focus on understanding concepts and applying formulas for surface area and volume of space buildings. In contrast, the Merdeka Curriculum emphasizes understanding based on direct experience through explorative activities. In this curriculum, teachers have a greater role in determining

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

material delivery strategies, so that competency standards are more flexible and oriented towards problem solving and project-based learning.

This difference has implications for the development of student worksheets. In the more structural 2013 Curriculum, the worksheets developed must ensure that there are learning stages that are in accordance with the Core Competencies and Basic Competencies and a systematic presentation of material so that learning takes place in accordance with the applicable curriculum. Meanwhile, in the context of the Merdeka Curriculum, the student worksheets must be designed to allow exploration of concepts through more open and project-based activities, so that students can build their understanding independently. Therefore, in its development, the student worksheets must have flexibility in its use so that it can be applied to both curricula while still being oriented towards improving students' mathematical generalization skills.

As a result of this study, it was found that the development of CAIs by teachers varies and lacks standardization. These indicators play a crucial role in ensuring that learning objectives are met, yet in practice, there are differences in their interpretation and formulation. Table 4 presents a summary of the Competency Achievement Indicators gathered in this study, reflecting how teachers apply and develop these indicators within the context of mathematics instruction at this school.

Table 4. Curriculum analysis

Core Competencies		Basic Competencies		Competency Achievement Indicators	
3.	Understanding knowledge (facts, concepts and processes) through curious scientific, technological, artistic and cultural pursuits)	3.9	Distinguish and determine the surface area and volume of flat-sided spaces (cubes, blocks, prisms and pyramids)	3.9.1	Try to process and serve in the concrete (spending, construing, amassing, transforming, and creating) and abstract (recording, reciting, calculating, scratching, and composing) domains according to what is learned in school and other similar sources in the point of view/theory. Describe flat-sided spaces (cubes, beams, prisms, and pyramids)
				3.9.2	Find the radius of flat-sided spaces (cubes, blocks, prisms, and pyramids)
				3.9.3	Find the formulas of surface area and volume of flat-sided spaces (Cube, block, prism, and pyramid)
				3.9.4	Presenting problems related to flat-sided spaces (cubes, beams, prisms, and pyramids)
4.	Try to process and serve in the concrete (spending, construing, amassing, transforming, and creating) and abstract (recording, reciting, calculating, scratching, and composing) domains according to what is learned in school and other similar sources in the point of view/theory	4.9	Solve problems related to the surface area and volume of flat-sided spaces (cubes, blocks, prisms and pyramids) and their combinations	4.9.1	Solve problems related to the surface area and volume of flat-sided spaces (cubes, blocks, primes and pyramids), and their combinations

3.1.2. Material Analysis

The analysis of learning materials is conducted based on the Core Competencies, Basic Competencies, and Competency Achievement Indicators established during the competency analysis phase. This process aims to determine the most relevant materials for the development of student

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

worksheets by referring to appropriate sources within the scope of the Basic Competencies. The next step involves identifying the main topics along with supporting references and outlining the subtopics to be developed in the student worksheets.

The main subtopics developed include: (1) introduction of elements and properties of flat-sided spaces, (2) concepts and definitions of flat-sided spaces, (3) calculation of surface area, and (4) calculation of volume of flat-sided spaces such as cubes, blocks, prisms, and pyramids.

The inductive approach is applied to each subtopic with the learning stages starting from the presentation of concrete examples before moving towards abstract understanding. In the first subtopic, students are invited to observe various spatial shapes through pictures, concrete models, or manipulation of real objects. They are then asked to identify the elements that make up the shapes and understand their properties.

In the second subtopic, students explore the concepts and definitions of flat-sided spaces through investigative activities, such as connecting observed characteristics with formal definitions in mathematics. In the third subtopic, the calculation of surface area is introduced by asking students to look for patterns in the area of the sides of a shape before formulating the general concept of surface area.

Similarly, in the fourth subtopic on volume, students are invited to build understanding by comparing the volume of various flat-sided spaces using unit cubes before compiling the volume formula inductively. Each subtopic in the student worksheet is designed to guide students to discover concepts gradually so that they can build a deeper and more meaningful understanding of flat-sided space building material.

3.1.3. Analysis of Learners Characteristics and Work Plan

At this stage, an interview was conducted with the mathematics teacher at the school to gain insights into students' prior knowledge, the scope of materials, and the topics necessary for solving problems related to three-dimensional geometric shapes with flat surfaces. Additionally, the interview aimed to identify various challenges encountered during the learning process. A written test was also administered to assess the level of students' mathematical generalization skills, as they would be the users of the student worksheet.

Based on interviews with mathematics teachers, it was found that students experience various difficulties in developing mathematical generalization skills. Some specific errors that students often make in solving mathematical generalization problems include: (1) difficulty in identifying patterns of a mathematical phenomenon, such as determining the number of unit cubes in a spatial pattern systematically; (2) inability to write patterns symbolically and formulate general rules based on the patterns found; (3) errors in performing symbolic manipulation, for example students often make mistakes in composing equations based on the patterns they have identified; and (4) lack of ability to prove the truth of the generalization results they make, where students tend to rely only on specific examples without verifying various other cases.

One of the mistakes that students often make in mathematical generalization is the difficulty in accurately identifying patterns. For example, when given a pattern of arranging unit cubes in blocks with increasing length at each stage, students often only see the relationship between the first two stages without checking whether the pattern applies to the next stage. Given a first stage with 2 cubes, a second stage with 4 cubes, and a third stage with 6 cubes, students conclude that the pattern increases by 2 at each stage, without realizing that the more general rule is $n \times 2$. As a result, when asked to determine the number of cubes in the fourth stage, they incorrectly answer 8 cubes without really understanding the underlying pattern. Similar to the study by Dani et al. (2017), the mistakes made by students in solving mathematical generalization ability tests include identifying patterns from mathematical phenomena to make generalizations.

To address this error, the student worksheet was designed by providing a data table that helps students record the number of cubes at each stage so that they can observe the development of the pattern more clearly. In addition, the worksheet directs students to explain the pattern using words before writing it in symbolic form, as well as providing explicit exercises that ask them to test whether the pattern found really applies to the next stage. With this approach, it is expected that students can develop a stronger understanding of mathematical patterns and improve their ability to make correct generalizations.

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

Furthermore, the student worksheet provides gradual exercises that start from problems with simple patterns to more complex patterns. In this stage, students are guided to write down the patterns found in the form of mathematical expressions. To overcome errors in symbolic manipulation, the worksheets include examples of the correct steps in formulating formulas and provide exercises with scaffolding in the form of instructions that direct students in preparing the right equation.

In addition, to improve students' ability to prove the generalization, the worksheet includes an exploratory activity where students are asked to test the rules they make against several different cases and provide justification for their correctness. With this approach, the worksheets not only help students understand the concepts deeply but also train them to think critically and independently in developing and verifying mathematical generalizations.

3.2. Design Phase

During the design phase, the student worksheet was developed based on prior analysis to ensure the relevance of both the content and instructional approach. This worksheet focuses on solid geometry with flat surfaces for eighth-grade students, incorporating the characteristics of the inductive approach. In designing the content, the first and second authors systematically structured the material using an inductive approach, which involves several key stages.

To mark the steps of the inductive approach, the "Specific Examples" icon is used in the form of a magnifying glass symbol that indicates that students are observing patterns from the examples given. After that, at the pattern exploration stage, the "Patterns and Hypotheses" icon is used in the form of a dotted diagram that helps students find general rules from the examples that have been studied. For the concept reinforcement stage, the "Supporting Evidence" icon is used in the form of a check mark indicating that students must confirm their hypothesis with several additional examples before coming to a conclusion. Meanwhile, the conclusion of the induction result is marked with an upward arrow-shaped "Generalization" icon, which symbolizes the transition from specific to general understanding.

In addition, the mathematical generalization ability indicators are also marked with different icons to distinguish them from the inductive approach. For example, when students are asked to identify patterns, the "Pattern Identification" icon is used in the form of a number chain that shows the relationship between elements. To make conjectures or predictions, a "Mathematical Hypothesis" icon in the form of a light bulb symbolizes critical thinking and proposing new ideas. At the proof and justification stage, the "Proof" icon in the form of a scale is used to signify the importance of logical balance in mathematical argumentation. Finally, when students have to apply generalizations to new situations, the "Application" icon in the form of a forked arrow symbolizes the application of concepts to different contexts.

With these symbols, the student worksheet is expected to be more structured and intuitive, so that students not only follow the learning flow mechanically, but also clearly understand how the process of induction and generalization takes place in mathematics learning.

In addition to designing the student worksheet, this phase also included the development of assessment instruments to measure students' mathematical generalization ability through both pre-tests and post-tests. These instruments were carefully structured to assess the extent to which students could generalize the concepts they had learned. Furthermore, various other instruments were prepared to ensure the validity and reliability of the developed worksheet. These included validation sheets, which would be evaluated by subject matter and media experts, as well as assessment sheets to gauge students' comprehension of the presented material. Thus, the development process not only focused on content creation but also ensured that the assessment tools used could yield accurate and reliable results.

At this stage, the identification and selection of validators were also carried out to evaluate the feasibility and effectiveness of the student worksheet before its implementation in the learning process. Four validators were designated for this study, consisting of experts in mathematics education, instructional design, and educational media. These validators will provide feedback and assessments to ensure that the developed worksheet meets the necessary pedagogical and didactic standards. With this validation phase, the student worksheet is expected to serve as an effective learning tool that enhances students' inductive thinking and mathematical generalization skills optimally.

3.3. Development Phase

The development phase is the translation of the design specifications from the design phase into physical form. This activity will produce a prototype development output in the form of student worksheets that are based on an inductive approach to the improvement of the mathematical

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

generalisation ability of flat-sided space materials. Concurrently, validation instruments are developed, including expert media validity instruments, learner response questionnaires, and pretest and posttest assessments for mathematical generalization ability. Following the validation of each instrument, the worksheet prototype is evaluated for its validity using a validated questionnaire. Table 5 shows how material and media experts rated the validity of student worksheets.

Table 5. Summary of validity of student worksheets by materials and media expert

No.	Assessment Aspects	Average	Category
1.	The instruction aspect	3,33	Valid
2.	The content aspect	3,79	Very Valid
3.	The language aspect	3,5	Very Valid
4.	The arrangement aspect	4	Very Valid
	Total Average	3,65	Very Valid

Table 5 demonstrates that the average scores from both content expert and media validators classify the student worksheet products as very valid. Consequently, the student worksheet products have been deemed valid and suitable based on the assessments of both content and media experts. Conversely, feedback and suggestions from media and materials experts are presented in Table 6.

Table 6. Feedback or recommendations from media and subject matter experts

Validator	Comments/Suggestions
Validator 1	Include elements of inductive learning in the text of the student worksheet
Validator 2	There are some writing techniques that still need to be tidied up and you should reduce unnecessary pictures, adjust to the character of students who are already in junior high school
Validator 3	Note the parts of the worksheet that are illegible because they are too small
Validator 4	Worksheet introduction language sharpened

The following are the inputs given by the validators and their implementation in the revision of the LKS.

a. Feedback from Validator 1: Addition of Inductive Learning Elements

Validator 1 provided input so that the inductive learning elements are more clearly visible in the content of the student worksheet. Before the revision, the questions in the worksheet were more direct without providing opportunities for students to find their own patterns. Therefore, in the revision, the inductive approach is strengthened by adding the stages of exploration, observation of patterns, making conjectures, and testing conjectures systematically. For example, in Activity Sheet 1 which discusses the properties of flat-sided spaces, previously students were only asked to directly calculate the number of sides, ribs, and corner points of several spaces. After the revision, the questions are arranged in a sequence that encourages students to find their own patterns, such as:

Before Revision:

- A cube has 6 sides, 12 ribs, and 8 corner points. A block has ... sides, ... ribs, and ... corner points.
- Compare your results with your friends!

After Revision:

- Observe the following figures and determine the number of sides, ribs, and corner points.
- What patterns can you find in the relationship between the sides, ribs and angles?
- Make a general guess about this relationship and discuss it with your group.
- Test your conjecture with other shapes!

b. Feedback from Validator 2: Editing Writing Techniques and Reducing Excessive Images

Validator 2 highlighted the need to improve writing techniques in the student worksheet to make it easier for junior high school students to understand and suggested reducing irrelevant images. The implementation of the revision was carried out by simplifying sentences that were too long and complex to be more concise and using more communicative language according to the level of student understanding. In addition, decorative images that do not have a direct function in learning are removed or replaced with more relevant illustrations. For example, in activities that ask students to identify the number of sides and ribs of a building, decorative illustrations that were previously only aesthetic in

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

nature are replaced with clearer and more proportional sketches of the building. This change aims to make students more focused in understanding the concepts learned without distraction from visual elements that do not support their mathematical thinking process.

c. Feedback from Validator 3: Improvement of Text Size and Readability

Validator 3 observed that some parts of the LKS had writing that was too small, making it difficult for students to read and understand the instructions. To overcome this problem, revisions were made by increasing the font size in the instructions and tables from 10 pt to 12 pt to make it easier to read. In addition, some tables that previously had too narrow columns were expanded so that the information presented was clearer and did not appear dense. These changes aim to improve students' comfort in using the LKS, so they can focus more on understanding the material without visual barriers.

d. Feedback from Validator 4: Language Refinement in the Introduction Section

Validator 4 suggested that the language used in the introduction of the LKS should be more sharp and communicative so that it can attract students' interest from the beginning. To implement this feedback, the sentences in the introduction section that were previously too formal were changed to be more interactive and build student engagement. Before the revision, the introduction reads: "This student worksheet is designed to help students understand the concept of building space inductively. Students will learn through observation and exploration of mathematical patterns in various spatial figures". This sentence was then revised to: "Have you ever noticed how the shapes of the spaces around you look like? For example, a block-shaped cardboard box or a ball that resembles a curved-sided space. In this worksheet, you will discover interesting patterns in the shapes and use them to solve various mathematical challenges!" This change aims to make students more interested and feel that the learning in the worksheet is relevant to their daily lives.

Once we checked that the product was valid, we made some changes based on what the material and media experts said. The accompanying image illustrates several of these alterations.

Figure 2. Before the revision (left) and after the revision (right)

3.4. Implementation Phase

Student worksheets, following validation and approval by the validator, can be implemented in either large-scale or experimental classes. Prior to large-scale implementation, these worksheets underwent a pilot test with a small group of 30 randomly selected students. Students completed student response questionnaires to assess the practicality of the worksheets following the implementation of teaching and learning activities using the student worksheets. These worksheets had undergone prior validation by material and media experts. After a successful small-scale class trial, the worksheets were applied in a larger class setting with 31 students. All student activities during the learning process were

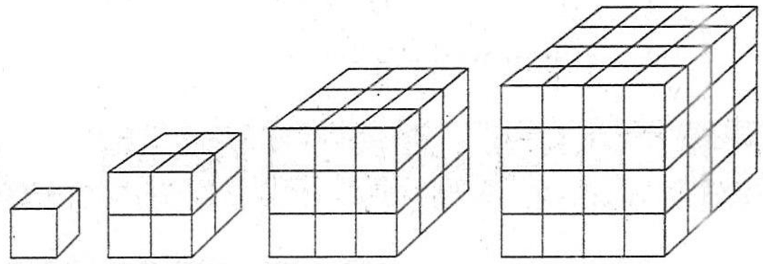
ISSN 2356-2684 (print), ISSN 2477-1503 (online)

centered around these worksheets. The following section details the implementation activities conducted in the larger class.

3.4.1. Activities of The First Meeting

At the first meeting held on Tuesday, January 17, 2023, a pretest was conducted to identify students' initial abilities before using the LKS. This pretest consists of two description questions that test students' understanding of the concept of flat-sided spaces, such as:

1. Look at the arrangement of the cubes below!



If the cube in pattern 1 is a unit cube, and the following shapes are the arrangement of the first cube, determine:
   a. How many unit cubes are in pattern 1, pattern 2, pattern 3, and pattern 4?
   b. Draw the arrangement of the buildings in the fifth order! Give a reason!
   c. State a formula to determine the volume of the building in the nth pattern!
   d. Using the formula you have created, determine the volume of the fifth figure!
2. You are given two pyramids with rectangular base and have base length, base width and height as follows.

Limas	Base rib length	Base rib width	Limas height
Limas T.ABCD	**6 cm**	**5 cm**	**3 cm**
Limas T.EFGH	**6 cm**	**5 cm**	**6 cm**

   a. What is the volume of limas T.ABCD and limas T.EFGH?
   b. What is the height ratio between limas T.ABCD and limas T.EFGH?
   c. What is the volume ratio between limas T.ABCD and limasT.EFGH?
   d. If the height ratio of the two limas is p : q, then what is the volume ratio of the two limas?

The teacher instructs the students to solve the problems within 90 minutes individually. After that, students' answers are collected and analyzed to understand the patterns of errors that often appear in mathematical generalization related to flat-sided spaces.

3.4.2. Activities of The Second Meeting

The second meeting on Thursday, January 19, 2023, focused on introducing the student worksheet to students. The activity began with the formation of study groups consisting of 4-5 students. The teacher then explained how to use the student worksheet effectively and gave a brief overview of the activity structure in the student worksheet. In this session, students are given introductory material about the elements of flat-sided spaces, such as ribs, sides, and corner points. One of the tasks in the worksheet is to ask students to observe pictures of several flat-sided shapes and fill in the table of the number of ribs, number of sides, and number of corner points of the shapes. Figure 3 illustrates the meeting's activities.

Figure 3. Activities of the second meeting

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

The teacher acts as a facilitator by providing triggering questions to encourage students to identify patterns from the number of sides, ribs, and corner points of each building.

3.4.3. Activities of The Third Meeting

On Tuesday, January 24, 2023, students began to actively use the student worksheet in learning. The activities carried out in this session focused on understanding the properties of flat-sided spaces through student worksheet Activity Sheet 1. Students were asked to observe pictures of various spaces and describe their characteristics. The teacher provides guidance by asking questions to the students to guide them in finding the relationship between the elements of flat-sided spaces.

3.4.4. Activities of The Second Meeting

The fourth meeting, held on Thursday, January 26, 2023, involved continued student learning using Student Worksheets. Specifically, students engaged with Activity Sheet 2, focusing on the concept of flat-sided spaces through realistic problem-solving. Guided by a cube model provided by the teacher, students followed a structured approach encompassing contextual application, use of model, learner construction, interactive engagement, and linkage. Student feedback indicated that the use of Student Worksheets incorporating these steps facilitated their understanding of flat-sided spaces. A visual representation of student activities during this session is presented in Figure 4.

Figure 4. Learning activities in the fourth session

3.4.5. Activities of The Fifth Meeting

On Tuesday, January 31, 2023, students worked on Activity Sheet 3 which focused on developing mathematical generalization skills in calculating the volume of a space. One of the challenges in the worksheet is:

"If a cube with a rib length of 2 cm has a volume of 8 cm³, determine the volume of cubes with rib lengths of 3 cm, 4 cm, and 5 cm. Find the pattern of the relationship between rib length and cube volume and write down the general formula."

At this stage, the teacher directs students to develop patterns and make conjectures based on the results of their calculations. The teacher also assists students in testing the validity of their conjectures by providing additional, more complex examples.

3.4.6. Activities of The Sixth Meeting

On Thursday, February 2, 2023, the last meeting was conducted by holding a posttest. This posttest consisted of two description questions similar to the pretest, with the aim of measuring the increase in student understanding after using the LKS.

Students were asked to work on the problems individually within 90 minutes. The teacher observed and recorded how students strategized in solving the problem. After the posttest was completed, the results of students' answers were analyzed to see the extent to which their mathematical generalization ability improved after using the LKS. Student engagement during the posttest is depicted in Figure 5.

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

Figure 5. Students working on questions for the post-test

3.5. Evaluation Phase

At the evaluation stage, the assessment is conducted by comparing the results of a validated mathematical generalization ability test. This measurement includes the pre-test scores administered before the intervention and the post-test scores given after the intervention in the experimental class. Prior to the post-test, students in the experimental class were first provided with the product as part of the learning process. The effectiveness of using the product to enhance generalization ability in the topic of three-dimensional geometric shapes with flat surfaces is analyzed by comparing the pre-test and post-test results, allowing for an assessment of the extent to which students' understanding improved after using the product.

To ensure the validity of the analysis, statistical tests were conducted. First, a normality test (Kolmogorov-Smirnov) was conducted to determine whether the pre-test and post-test data followed a normal distribution. The results showed that the significance value = 0.072 > α = 0.05 which means the data was normally distributed. After that, a homogeneity test (Levene's test) was conducted to assess the equality of variances between the two sets of data, with the results showing a significance value = 0.106 > α = 0.05 which means that the data is homogeneously distributed. Finally, a paired sample t-test was conducted to analyze the significance of the difference between the pre-test and post-test scores. The result shows that the significance value = 0.000 < α = 0.05, which means there is a difference between the pre-test and post-test scores after being given the worksheet based on the inductive approach. Thus, there is a significant improvement in students' mathematical generalization ability after using the product.

Additionally, at the same stage, students were given a questionnaire to measure their responses to the learning experience using worksheets based on an inductive approach. This questionnaire aims to explore students' perceptions and levels of engagement throughout the learning process. By combining the test results and questionnaire analysis, this evaluation not only assesses the improvement in mathematical generalization ability but also examines the effectiveness and appeal of the product used in the learning process. The following are some comments from the students:

Student1: "The worksheet helps me understand the concept more easily because it guides me step by step."

Student5: "I enjoy doing this worksheet because it makes learning more interactive and less monotonous."

Student12: "Sometimes, I found certain parts a bit difficult to follow, but discussing with peers really helped."

3.6. Discussion

Inductive learning of mathematics starts from examples to understand a concept. (Joyce et al., 2011) divide three phases of inductive learning strategy, namely: concept learning, data interpretation and principal application. Concept formation is a complex thinking process that includes comparing, analysing and classifying and inductive reasoning as well as the result of an understanding (Gerhard, 1971). Students gain experience when making careful direct observations on student worksheets

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

provided by the teacher, in constructing this flat-sided space building material students are involved with the process of adaptation and organisation, so that learning mathematical concepts in this way is seen as more meaningful than just memorising them.

This research aims to develop inductive approach-based student worksheets to improve mathematical generalization ability on flat-sided geometric shapes. The findings demonstrate that the developed worksheets fulfill aspects of validity, practicality, and effectiveness in learning. The results show that the inductive approach used in student worksheets enhances student engagement, critical thinking, and mathematical generalization skills.

These findings align with previous studies that support the effectiveness of inductive approaches in improving students' conceptual understanding and engagement. Hudojo (2005) found that inductive learning allows students to observe patterns before drawing general conclusions, facilitating deeper comprehension. Additionally, Sari & Surya (2019) reported that the inductive approach significantly enhances student motivation and conceptual understanding. Prince & Felder (2006) further confirmed that induction-based learning positively impacts students' critical thinking skills.

From a practical perspective, these results have significant implications for teachers and curriculum developers. Teachers can integrate inductive-based worksheets into their instructional strategies to promote active learning and student independence. By encouraging students to explore examples, identify patterns, and derive generalizations, teachers can help students develop higher-order thinking skills. Additionally, curriculum developers should consider incorporating structured inductive activities into mathematics curricula to ensure systematic skill development in students.

The results of the curriculum analysis indicate that, although the 2013 Curriculum and the Merdeka Curriculum accommodate the teaching of flat-sided geometric shapes, challenges persist in implementation. One major issue is the lack of clearly defined competency achievement indicators, making it difficult for teachers to systematically assess learning outcomes. The structured design of the developed worksheets addresses this gap by providing a clear progression from concrete examples to abstract generalizations, facilitating student understanding.

Moreover, an analysis of learner characteristics reveals that many students struggle with mathematical generalization, particularly in identifying patterns and independently formulating mathematical rules. Interviews with teachers indicate that students tend to rely heavily on direct instruction, lacking confidence in abstract reasoning. The implementation of inductive-based worksheets in this study contributes to reducing students' dependence on teacher explanations while training them to develop logical thinking independently.

Validation by material and media experts showed that the developed worksheets met high validity criteria with an average score of 3.65. These results indicate that the instructional design in the student worksheets is in accordance with applicable learning standards and can be used as an effective learning tool. In addition, suggestions from validators regarding improving the readability aspect and simplifying the images used in the student worksheets have been implemented in the final revision, so that the student worksheets becomes more in line with student needs.

The small and large scale trials showed that the application of the inductive approach-based Student Worksheet received positive responses from students. The students showed an increase in their involvement, especially in identifying patterns, formulating hypotheses, and making generalisations about the concepts learned. This is in line with research conducted by Sari & Surya (2019) which states that the inductive approach in learning can significantly increase students' motivation and understanding of mathematical concepts. In addition, a study by Prince & Felder (2006) also confirmed that induction-based learning has a positive impact on students' critical thinking skills.

This study began with the implementation of a pretest to measure the mathematical generalisation ability of class VIII students at the first meeting. From the descriptive statistical analysis, it was found that the average value obtained by students in the pretest was 59.84. The data was used as an initial benchmark before the implementation of inductive approach-based learning. Furthermore, learning was carried out in accordance with the stages of inductive learning, where students were given the opportunity to explore various examples and observe images or objects related to the concept of mathematical generalisation. Students are also directed to actively participate in group discussions, which according to research Kawuri et al. (2019) and Nicol et al. (2018) can improve their understanding and analytical thinking skills. The interaction that occurs in this discussion is an important factor in the teaching-learning process.

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

The student worksheets developed in this study were designed by considering several main aspects, namely (1) instructions for use, (2) material content, (3) language, and (4) layout. This worksheet plays an important role in helping students in group work and building their understanding of flat-sided space building materials. Interestingly, for most of the students, this was their first experience using the student worksheets as a learning tool, as their teachers had never provided this kind of learning media before. (Muslimah, 2020) asserts that student worksheets is one of the media that can facilitate interaction between students and teachers, increase learning effectiveness, and have a positive impact on student learning activities and achievement.

On the sixth meeting, a post-test was conducted to evaluate the extent of the improvement of students' mathematical generalisation ability after using the inductive-based student worksheets. The analysis showed that the average post-test score increased to 79.44, which exceeded the Minimum Completion Criteria of 70. This indicates that students have successfully achieved the expected indicators of mathematical generalisation. Rizkiyah & Rahaju (2018) asserted that mastery of generalisation skills is very important because it helps students understand the material more deeply, improve mathematical communication, and broaden their horizons in solving problems. In addition to the post-test, a questionnaire was also given to students to determine their level of acceptance of this learning method. The results showed that the average positive response of students reached 95%, far above the minimum limit of 70% set by Basri (2019) to assess the effectiveness of a learning method.

The paired samples t-test analysis shows that the significance value (Sig. 2-tailed) is 0.000, which is less than 0.05. This confirms that there is a significant difference between the pre-test and post-test scores. With an average pre-test of 59.84 and post-test of 79.44, and an n-Gain value of 0.51, this increase is included in the moderate category. This is in line with research (Russefendi, 1991), which states that the application of the inductive approach in learning mathematics can improve students' conceptual understanding and analytical thinking skills. Therefore, based on the data obtained, it can be concluded that the use of inductive-based student worksheets is effective in improving students' mathematical generalisation ability. This is supported by the statement that a development product can be said to be effective if the product has provided results that are in accordance with the purpose for which the product was developed (L et al., 2020). With the effectiveness, it can achieve the learning objectives that have been set (Suniasih, 2019). Thus, the results of this study contribute to practical evidence that the use of an inductive approach in student worksheets can enhance students' mathematical generalization skills.

Overall, the effectiveness of this student worksheets was evaluated by comparing students' pre-test and post-test results. The results of this study reinforce previous findings which state that learning with an inductive approach can improve students' conceptual understanding and have a positive impact on analytical thinking skills. Thus, the use of inductive-based worksheets can not only improve student learning outcomes, but also provide a more interactive and enjoyable learning experience. The results of this study are in line with previous studies that support the effectiveness of induction-based learning in improving students' understanding and motivation in learning mathematics (Nicol et al., 2018; Prince & Felder, 2006; Tharayil et al., 2018).

Comparison with previous research shows that the inductive approach in mathematics teaching has been widely used to improve students' understanding of abstract concepts. However, this study makes a new contribution by developing an inductive approach-based worksheet specifically designed to improve mathematical generalisation skills. Thus, the results of this study enrich the study of learning strategies that are effective in improving students' mathematical thinking skills.

Although the results showed high effectiveness, there are some limitations that need to be noted. One of them is the limitation in the scope of learners tested, which only involves one school. Therefore, further research is recommended to involve a wider sample to ensure stronger generalisation of the results. In addition, this study is still limited to the mathematical generalisation aspect without considering other cognitive aspects that also play a role in understanding mathematical concepts.

Overall, this study shows that inductive approach-based worksheets can be an effective tool in improving students' mathematical generalisation ability. By applying learning strategies that focus on concept exploration and logical thinking patterns, students can be more independent in understanding and applying mathematical concepts in various situations. These findings provide important implications for the development of future teaching materials, especially in the context of mathematics education at the junior secondary level.

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

CONCLUSION

From the research results, it was concluded that the inductive approach-based student worksheets were valid, practical, and effective. The validity of this worksheet is confirmed through the assessment results from material experts and media experts who gave an average score of 3.65, which is included in the very valid category. In addition, the practicality aspect was assessed based on students' responses to the questionnaire, which showed an acceptance rate of 95%. This indicates that the inductive-based student worksheet is easy to use and in accordance with the needs and characteristics of students. The effectiveness of this student worksheet in improving generalisation skills is also evident from the significant difference between the pre-test and post-test results, where the average post-test score is higher than the pre-test. The increase is in the moderate category, indicating that the use of inductive-based worksheets can have a positive impact on broader and deeper concept understanding.

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PROFIL SINGKAT

Nirfayanti lahir di Laccibunge yang berada di bone, Makassar pada tanggal 30 November 1989 dari pasangan Hajar Ponda dan Nickma. Pendidikan formal dimulai dari SD Inpres 12/79 Ulubalang,

ISSN 2356-2684 (print), ISSN 2477-1503 (online)

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ISSN 2356-2684 (print), ISSN 2477-1503 (online)