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Development of Inquiry-Based Learning Tools to Enhance Students' Learning Interest and Conceptual Understanding in Mathematics

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Abstract

This study aims to develop an inquiry-based mathematics learning tool that is valid, practical, and effective in enhancing students' learning interest and conceptual understanding. Unlike previous studies, this research focuses on the development of inquiry-based learning tools to enhance learning interest and conceptual understanding of mathematics among elementary school students, specifically within the context of education in Lombok. The research employed a Research and Development (R&D) approach using the 4-D model (Define, Design, Develop, Disseminate). The participants consisted of 26 fourth-grade students at SDN 4 Pringgabaya, East Lombok. The instruments used included learning material validation sheets, teacher and student response questionnaires, a learning interest questionnaire, and a conceptual understanding test. Data were collected through document analysis, questionnaires, and tests, then analyzed descriptively using percentage categories and N-gain Test. The findings revealed that all components of the developed instructional materials were rated "very valid" by experts. During the implementation phase, the materials were rated "very practical" (86.67%) based on teacher responses. Post-intervention data indicated that 88.46% of students reached the "very high" category of learning interest, while 81% met the minimum mastery criteria for conceptual understanding. The results of the N-Gain test show an average N-Gain value of 0.7166, which falls into the high category. This indicates an improvement in students' conceptual understanding. These results confirm that the inquiry-based learning materials developed in this study are valid, practical, and effective in improving students' interest and conceptual understanding in mathematics. The success of this learning tool can make a contribution to educational policies at the regional level, with relevance to the development of an inquiry-based curriculum approach that can be more widely implemented in elementary schools.

Keywords: Learning Tools; Inquiry-Based Learning Model; Learning Interest; Mathematical Conceptual Understanding

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INTRODUCTION

Learning interest in mathematics refers to students' emotional and cognitive engagement when interacting with mathematical concepts. It has been proven to be a critical predictor of academic success, especially for students who have previously struggled with the subject (Bright et al., 2024; Wong & Wong, 2019). Students with high interest typically demonstrate greater intrinsic motivation, perseverance, and determination when facing learning challenges (Pangadongan et al., 2022; Yuliani, 2021). Indicators of learning interest include positive emotional responses to mathematics, cognitive engagement in understanding materials, active participation in learning activities, self-perception of mathematical ability, and a desire for continuous learning (Azhari et al., 2023; Nahdi et al., 2023).

On the other hand, low learning interest is closely related to weak conceptual understanding of mathematics. Conceptual understanding refers to the ability to relate, explain, and flexibly represent mathematical ideas in various contexts (Harianja et al., 2020; Lena et al., 2023). Research has shown that many elementary students in Indonesia still struggle to grasp basic concepts, as evidenced by their difficulties in solving problems requiring deep understanding, making connections between concepts, or applying them in real-life situations Pratama et al., (2022) This presents a serious challenge for education, considering that conceptual understanding serves as a foundation for mastering advanced mathematics and applying it in everyday life.

Such issues of low learning interest and poor conceptual understanding are also evident at SDN 4 Pringgabaya, East Lombok. Many students show little enthusiasm during lessons, lack interest in the subject matter, and often pay minimal attention to teachers' explanations. Some students are distracted, talking to peers or engaging in other activities during class. With regard to conceptual understanding, students still face difficulties in restating concepts, translating symbols or formulas, and applying the correct formulas to solve problems. These findings indicate the need for more interactive and student-centered learning methods to enhance students' mastery of fundamental mathematical concepts.

One approach proven effective in improving both interest and conceptual understanding is Inquiry-Based Learning (IBL). According to Colburn (2000), inquiry-based learning is an approach that emphasizes the process of investigation and discovery by students through the questions they pose, experiments, as well as the collection and analysis of data to develop their understanding. This model emphasizes active student involvement in formulating questions, exploring data, conducting investigations, and reflecting on knowledge gained either independently or collaboratively (Nugroho & Zulfiani, 2021; Syahgiah et al., 2023) the context of mathematics education, the inquiry approach allows students to discover concepts through meaningful learning experiences, increase their curiosity, and strengthen logical connections between prior and new knowledge Farida et al., (2019). Multiple studies have confirmed that inquiry-based learning not only makes mathematics more appealing but also deepens students' understanding of its structure and applications (Hidayati et al., 2021; Wahyudin et al., 2024).

The inquiry-based learning model is relevant in enhancing students' interest and conceptual understanding of mathematics. According to Huda et al. (2022), inquiry-based mathematical literacy can stimulate students' critical thinking abilities, which are directly related to their understanding of mathematical concepts. Furthermore, Nasution et al. (2018) show that the use of guided inquiry learning models significantly improves students' critical thinking skills compared to traditional models. This aligns with the findings of Kalogeropoulos et al., who note that the challenge of student engagement in inquiry-based learning enhances mathematical concept understanding (Kalogeropoulos et al., 2021). The inquiry syntax, which includes systematic steps such as posing questions, designing experiments, collecting data, and drawing conclusions, facilitates students in developing a deeper understanding of the concepts taught. This process encourages cognitive engagement, where students actively think and analyze the information they receive, as well as affective engagement, which is related to students' feelings towards the learning. By providing students the opportunity to explore the material independently or in groups, they become more emotionally involved, which in turn increases their learning interest. The inquiry syntax allows students to connect new concepts with existing knowledge, reinforcing their conceptual understanding. This model suggests that the systematic structure of inquiry syntax not only increases students' interest but also deepens their understanding through an active process of organizing and analyzing information in a structured manner, giving them a sense of ownership over their learning. Thus, inquiry-based learning serves as a key driver in enhancing student engagement both cognitively and affectively, ultimately improving their interest and conceptual understanding of the material being studied.

Interviews with teachers at SDN 1 Pringgabaya revealed that they had never systematically developed or used inquiry-based instructional tools in teaching mathematics. Most of them still rely on conventional methods such as lectures and routine exercises. Although some teachers reported encouraging students to ask questions or participate in discussions, these activities were not organized within a complete inquiry learning model, which involves steps such as formulating questions, investigating, analyzing data, and reflecting on findings. The absence of structured inquiry-based learning materials contributes to students' low engagement. Students tend to be passive, unmotivated, and view mathematics as a difficult subject irrelevant to daily life. This situation is in line with Holidun et al., (2018), who noted that low interest negatively affects students' problem-solving abilities. Furthermore, students' conceptual understanding is often limited to memorizing formulas without comprehending their meanings and applications. As noted by Pratama et al., (2022), this lack of understanding hampers students' ability to connect mathematical concepts across topics and in real-life contexts.

The unavailability of structured inquiry-based learning tools limits the opportunities to foster active student engagement and build meaningful conceptual understanding. Therefore, the development of these learning tools is crucial to enhance the quality of mathematics education in a more enjoyable and meaningful way for elementary school students. Unlike previous studies, this research introduces a new approach to the development of inquiry-based learning tools that not only focuses on students' cognitive aspects but also includes the development of attitudes and deeper learning interest, especially for early-grade students. This study brings novelty by applying inquiry-based learning theory in the context of mathematics education in Lombok, which has been rarely explored, aiming to enhance both emotional and cognitive student engagement. Furthermore, this study emphasizes the importance of implementing inquiry-based learning in early-grade mathematics education, with special attention to the often-overlooked need for developing students' learning interest and conceptual understanding in previous studies. Unlike previous studies—such as Nurdin et al., (2019), which developed group investigation-based worksheets for junior high schools, and Akili et al., (2022), which applied the Argument-Driven Inquiry model in science—this research focuses on elementary-level mathematics using a more contextualized approach. This approach also integrates local contexts that are closely related to students' daily lives in Lombok, such as the use of traditional food *serabi*, the *cidomo* cart wheels as transportation tools, and geometric patterns found in mosque ornaments or traditional houses as media for mathematical inquiry. This study offers an enhancement of previous models by emphasizing meaningful learning based on local context

This research introduces new elements in the development of inquiry-based learning tools. The developed Lesson Plan (RPP) incorporates a more structured IBL syntax, ensuring that each stage of the learning process is well integrated to support the simultaneous development of students' conceptual understanding and learning interest. This tool also adopts the Student Worksheet (LKPD) format, which is designed to support the implementation of the inquiry-based approach with more structured and easily understandable steps for early-grade students. The LKPD also integrates interactive elements that facilitate students in exploring mathematical concepts independently and collaboratively, while promoting the simultaneous development of their cognitive and affective skills. Furthermore, this study introduces a deeper contextual approach by relating learning material to the local culture in Lombok. For instance, in certain topics, students are given the opportunity to learn through case studies involving local contexts, such as the use of traditional patterns in mathematics or measurements related to their daily lives. This approach is expected to increase the relevance of learning for students, strengthen their understanding of the material, and build a closer connection between the knowledge taught and their real-world experiences. Thus, these new elements not only enrich the substance of the learning process but also have a greater impact on student engagement and their conceptual understanding.

The uniqueness of this study lies in its integrative emphasis on both affective and cognitive dimensions, acknowledging the importance of engaging learning interactions that promote student involvement (Astari et al., 2024; Holidun et al., 2018). The materials developed not only facilitate conceptual understanding but are also intentionally designed to cultivate curiosity and motivation through the systematic syntax of inquiry learning Nugroho & Zulfiani, (2021). Moreover, the approach is tailored to the local characteristics of Lombok students, who have not yet benefited significantly from mathematics learning innovations, thus making the materials highly relevant and applicable in the field. Accordingly, this study enriches the literature on inquiry-based learning material development and offers practical contributions to improving the quality of elementary mathematics education in Indonesia.

Based on the above background, a systematic effort is needed to develop inquiry-based mathematics learning materials that can stimulate interest and strengthen students' conceptual understanding from an early age. These materials are expected not only to align with pedagogical principles but also to be contextually relevant, adaptable to elementary students' characteristics, and capable of fostering active engagement throughout the learning process. The objectives of this study are to: (1) evaluate the feasibility of the developed inquiry-based learning tools; (2) assess the practicality of the learning tools in the context of mathematics education in early-grade classrooms, including their ease of use by teachers; and (3) measure the impact of the learning tools on students' learning interest and conceptual understanding in learning mathematics.

METHOD

Research Design

This study employed a Research and Development (R&D) approach. The development model used was the Four-D (4-D) Model proposed by Thiagarajan, Semmel, and Semmel, which consists of four main stages: Define, Design, Develop, and Disseminate. This model was selected due to its systematic structure, flexibility, and proven effectiveness in the development of learning resources across various educational contexts (Usman & Ibrahim, 2023; Kintoko & Jana, 2019). For further clarification, the research procedure is illustrated in Figure 1.

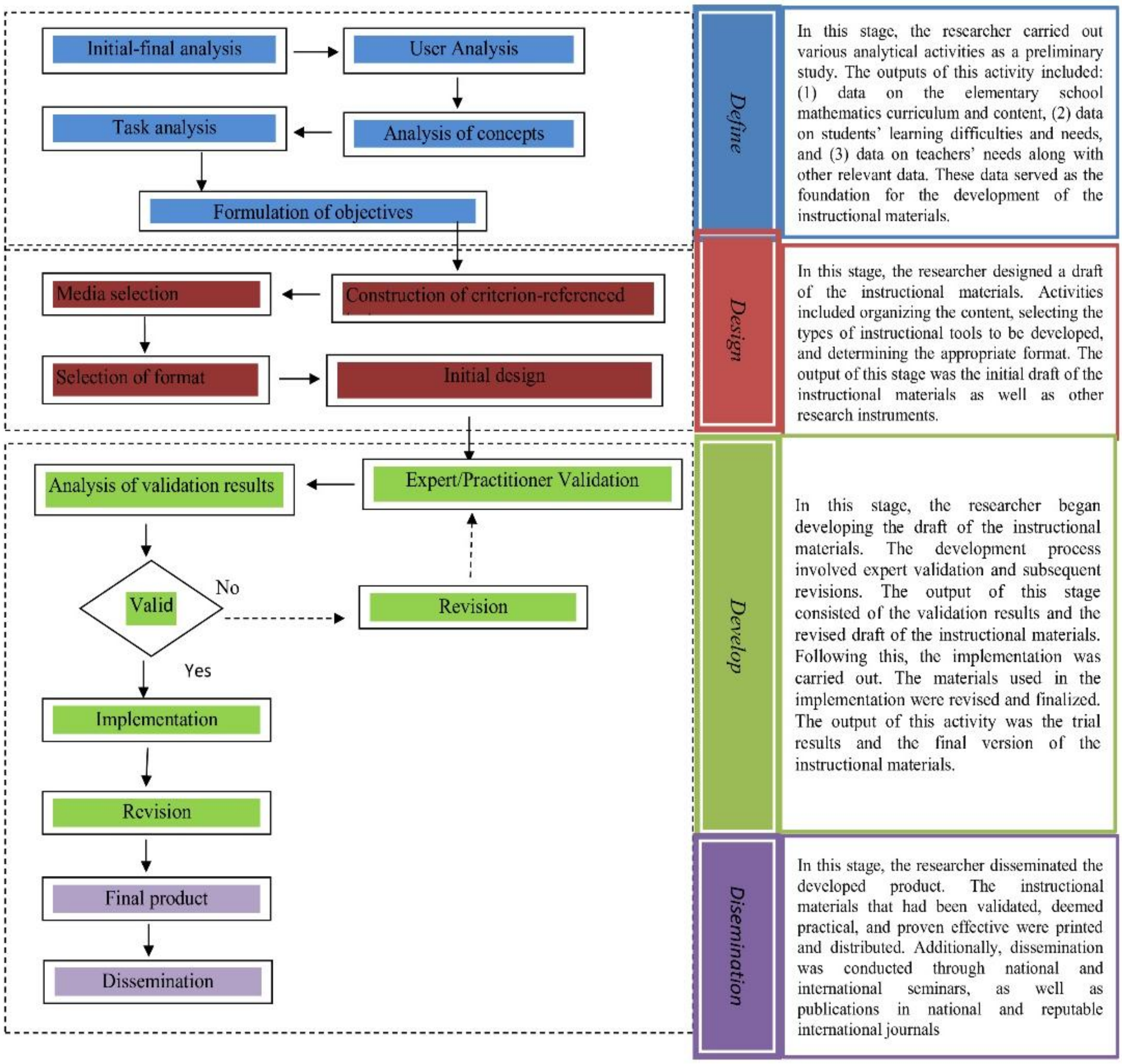


Figure 1. Research Flow Diagram

Research Subjects and Sampling

The subjects of this study are the fourth-grade students of SDN 4 Pringgabaya. The sample for this research was selected using a purposive sampling strategy, where 26 students from class IVA were chosen with the aim of ensuring that they had characteristics relevant to the research focus, specifically needing improvement in their mathematical understanding and learning interest. Although the sample used in this study is not random, we ensured that the selected students reflect a low level of conceptual understanding and mathematical learning interest, so that the findings of this study can provide a relevant representation for the context of mathematics education in the region. Therefore, while the sample is not fully representative of the entire population, the selection of students was made considering criteria that support the internal validity of the research. The determination of this sample size takes into account the limitations of the research and development (R&D) design, as well as the primary focus on testing the applicability of the learning tools within a real classroom context. As an initial stage study, this approach aligns with the characteristics of formative research, which prioritizes depth of insight over generalizability of findings.

Research Instruments

The research instruments in this study were developed to obtain data on the validity, practicality, and effectiveness of the learning tools in enhancing students' interest and conceptual understanding in mathematics. Each instrument underwent expert validation to ensure content appropriateness, linguistic clarity, and measurability.

Learning Materials Validation Sheet

This instrument was used to evaluate the quality and feasibility of the developed learning materials, including the Lesson Plan (RPP), Student Worksheets (LKPD), Learning Interest Questionnaire, and Conceptual Understanding Test. The validation technique in this study follows the design and development model proposed by Akker, Gravemeijer, McKenney, and Nieveen (2006), recognized as the design research model in educational research and development. This model is used to develop and validate learning innovations iteratively, testing the effectiveness of learning designs in real-world contexts. The validation process involves an initial test of the design prototype, followed by reflection and improvement based on feedback from validators such as subject matter experts, teachers, and students, who assess the feasibility, practicality, and effectiveness of the learning tools. In addition to assessing the content validity and alignment with learning objectives, this model also includes testing the effectiveness of the learning process and evaluating the practicality of the tools in the classroom. This approach ensures that inquiry-based learning tools are not only theoretically valid but also practical and effective in real educational contexts, with the goal of improving students' learning outcomes in a sustainable manner.

Validation was conducted by two subject-matter experts and two instructional design experts. The assessed aspects included the clarity of objectives, accuracy of content, alignment with the inquiry-based learning syntax, communicative use of language, and visual appeal. The evaluation used a 4-point Likert scale. We conducted an inter-rater reliability test to ensure that the assessment of the learning tools was carried out consistently and objectively by the validators. To measure inter-rater reliability, we used Cohen's kappa coefficient.

Teacher Response Questionnaire

The teacher response questionnaire was designed to assess the practicality of the inquiry-based instructional tools after classroom implementation. Practicality in this context refers to ease of use, feasibility in classroom settings, and usefulness in supporting mathematics learning in elementary school.

Mathematics Learning Interest Questionnaire

This instrument was designed to measure changes in students' interest in learning mathematics before and after using the learning materials. The questionnaire consisted of 20 statements using a 5-point Likert scale and was developed based on four key indicators: (1) Enjoyment: reflects enthusiasm and pleasure during mathematics lessons; (2) Student Engagement: indicates the extent of students' active participation in classroom activities; (3) Student Attention: describes students' level of focus and attentiveness to the material presented; and (4) Interest: signals students' curiosity and inclination to continue learning mathematics.

Mathematics Conceptual Understanding Test

This test aimed to measure students' understanding of mathematical concepts, particularly on the topic of circles. The questions were constructed in essay format, aligned with a constructivist approach and the syntax of inquiry-based learning. The test was based on four indicators of conceptual understanding: (1) Restating Concepts: assesses students' ability to define and explain circle components such as radius, diameter, and circumference; (2) Providing Examples and Non-Examples: evaluates students' understanding by asking them to identify circular objects in daily life; (3) Using Appropriate Procedures: measures students' ability to use the formula for the circumference of a circle to solve calculation problems; and (4) Applying Concepts or Algorithms in Problem Solving: examines students' skills in applying the concept and formula of circumference in real-life problem contexts.

Data Collection and Analysis Procedure

Data collection was conducted systematically and in layers to obtain accurate and relevant information regarding the validity of the materials, their practicality in classroom application, and their effectiveness in improving students' learning interest and conceptual understanding.

Analysis of the Validity Level of Learning tools

The validation process was conducted to assess the quality and feasibility of the developed learning materials, including the Lesson Plan (RPP), Student Worksheet (LKPD), practicality questionnaire, learning interest questionnaire, and conceptual understanding test. The validation was carried out by subject-matter and media experts using instruments that contained several statements rated on a 4-point scale. Quantitative data were obtained from the scoring results using Formula 1.

$$Validity\ persentage\ (\%) = \frac{Total\ scor\ obtined}{Maximum\ possible\ scor}\ x\ 100\% \qquad (1)$$

The results of this calculation were then used to determine the feasibility level of the learning tools. Table 1 presents the interpretation criteria of the validity percentage scores, adapted from Riduwan in Indirayani (2023).

Table 1. Validity Criteria for Learning Tools

Interval percentage (%)	Validity Criteria
80 < Score ≤ 100	Very valid
60 < Score ≤ 80	Valid
40 < Score ≤ 60	Fairly valid
20 < Score ≤ 40	Less valid
0 < Score ≤ 20	Not Valid at All

Analysis of the Practicality of the Mathematics Learning tools

Data on the practicality of the instructional materials were obtained from the teacher response questionnaire, which applied a rating scale. The percentage of practicality was calculated using Formula 2.

$$Practicallity\ percentage\ (\%) = \frac{Total\ scor\ obtined}{Maximum\ possible\ scor}\ x\ 100\% \qquad (2)$$

To determine the level of practicality, the average of all teacher response percentages was calculated and interpreted qualitatively based on Table 2.

Table 2. Practicality Criteria for Learning Tools

Percentage (%)	Practically Criteria
80< Score ≤100	Very practical
60< Score ≤80	Practical
40< Score ≤60	Fairly Practical
20< Score ≤40	Less Practical
0< Score ≤20	Not Practical at all

Following the implementation of the learning activities, the teacher who facilitated the use of the learning tools was interviewed using a semi-structured format to identify obstacles, strengths, and perceptions of the practicality and usefulness of the tools. Likewise, students were interviewed to gather insights into their learning experiences using the inquiry-based materials. The interview data were analyzed qualitatively to complement and enrich the quantitative findings.

Analysis of the effectiveness of the mathematics learning tools

The effectiveness of the developed mathematics learning tools was assessed based on the analysis of the Learning Interest Questionnaire and the Mathematical Conceptual Understanding Test. To analyze learning interest data, each student's individual interest score was calculated. The scoring of the interest questionnaire employed a 5-point Likert scale as presented in Table 3.

Table 3. 5-point Likert scale

Score	Positive Statement	Negative Statement
5	Strongly Agree	Strongly Disagre
4	Agree	Disagree
3	Somewhat Agree	Somewhat Agree
2	Disagree	Agree
1	Strongly Disagre	Strongly Agree

After calculating the total interest score for each student, the scores were then converted into percentages and interpreted using the criteria in Table 4. The learning tools are considered effective in increasing students' learning interest if at least 75% of the students achieve a “Very High” category. Meanwhile, the analysis of students’ mathematical conceptual understanding was conducted by determining both individual mastery and classical mastery. At the individual level, a student is considered to have achieved conceptual understanding if their score reaches the Minimum Mastery Criteria (KKM) of 70. The learning tools are considered effective in enhancing conceptual understanding if at least 75% of the students meet or exceed the KKM.

Table 4. Learning Interest Criteria

No.	Percentage Range	Criteria
1.	$81 \leq X < 100$	Very High
2.	$61 \leq X < 81$	High
3.	$41 \leq X < 61$	Firly high
4.	$21 \leq X < 41$	Low
5.	$0 \leq X < 21$	Very Low

A score of 70 as the Minimum Mastery Criteria (KKM) for the circle material at this school is based on the policy established in the school's curriculum. This KKM is used as the lower limit to assess individual student mastery. It refers to the minimum standard that students must achieve to be considered to have understood the basic concepts being taught.

In addition, we set 75% as the effectiveness criterion to measure the success of the learning tools, in accordance with the policies and guidelines in place at the school. This indicates a higher level of effectiveness in improving students' overall understanding. This aligns with the goal of not only achieving the KKM but also ensuring that the learning tools have a more significant impact on enhancing students' interest and conceptual understanding. The use of this figure is consistent with the guidelines applied in the school curriculum and has been adjusted to the expected level of success within the context of mathematics learning. Furthermore, the effectiveness of the learning tools in improving students' mathematical conceptual understanding is measured using the N-Gain formula (Formula 3). The normalized Gain criteria in Table 5 used to assess the category of the N-Gain score improvement.

$$N - \text{Gain} = \frac{Posttest\ Scor - Pretest\ Scor}{Ideal\ Scor - Pretest\ Scor} \quad (3)$$

Table 5. Criteria for N-Gain (g) Categorization

Scor Interval	Category
0.7 ≤ g	High
0.3 ≤ g < 0.7	Medium
g < 0.3	Low

Ethical Statement

This study was conducted in accordance with ethical standards for research involving human participants. Prior to data collection, permission was obtained from the school authorities at SDN 4 Pringgabaya, and informed consent was secured from the parents or guardians of all student participants. Participation was voluntary, and confidentiality of the students' identities and responses was strictly maintained throughout the research process. The instruments used, including questionnaires and tests, were validated for content and clarity, ensuring no psychological or academic harm. All procedures were reviewed to align with ethical research principles in educational settings.

RESULTS AND DISCUSSION

The results of this study are presented based on the development procedures outlined in the 4-D instructional development model. The following sections provide a detailed explanation of the development process, encompassing the Define, Design, Develop, and Disseminate stages.

Define Stage

This stage aims to identify and define the essential requirements for learning by analyzing the objectives and content boundaries of the instructional materials to be developed. A curriculum and content analysis was conducted through document studies of the syllabus, lesson plans (RPP), student worksheets (LKPS) used by teachers, and the textbooks currently in use. The results revealed that the curriculum tends to emphasize procedural mastery of concepts, with minimal focus on fostering students' critical or exploratory thinking processes. The instructional materials were found to be largely directive, emphasizing formula memorization and repetitive exercises, without providing sufficient opportunities for students to construct understanding through investigative activities.

Data on students' difficulties and learning needs were gathered through interviews with teachers and classroom observations. Teachers reported that most students displayed low engagement during mathematics lessons, particularly when studying abstract topics such as circles. Students tended to be passive and struggled to relate the material to real-life contexts. Teacher-centered lectures still dominated classroom practices, leaving little space for students to think critically, ask questions, or explore concepts. These findings indicate that students' poor conceptual understanding is not solely due to cognitive limitations, but also results from instructional approaches that lack opportunities for meaningful learning. Among the topics perceived as most challenging was the concept of circles. Therefore, the instructional material selected for development focused on this specific topic.

Interviews also revealed that most teachers had never systematically used inquiry-based instructional tools. The main reasons cited were lack of training, time constraints, and the absence of ready-to-use reference materials. Teachers expressed difficulties in designing learning activities that could foster students' active participation and deepen conceptual understanding. These conditions further reinforce the urgency of developing inquiry-based instructional materials as a practical and applicable resource for classroom teachers.

Based on the analysis conducted, it can be concluded that a significant gap exists between the ideals of the curriculum and the realities of mathematics instruction in the field. Several key gaps were identified: teachers are not yet accustomed to employing inquiry-based approaches that encourage students to independently construct concepts. As a result, learning remains mechanistic and lacks exploration. This is consistent with findings by Akili et al., (2022) and Siti Rumaidah & Taufiqur Rahman, (2020), who reported the low implementation of inquiry in elementary mathematics classrooms. The lack of student engagement in the learning process is a clear indicator of limited meaningful learning experiences. Literature suggests that students' active interaction with instructional content significantly influences their motivation and understanding (Chalimi, 2023; Yusnita & Astriani, 2022). Without active engagement and contextualized content, students struggle to build comprehensive conceptual understanding. Inquiry-based approaches allow students to experience and understand concepts through scientific thinking and problem-solving processes; however, such approaches are still scarcely integrated into existing textbooks or instructional tools used in schools (Rosdiana & Hadikusuma, 2023; Siregar et al., 2022).

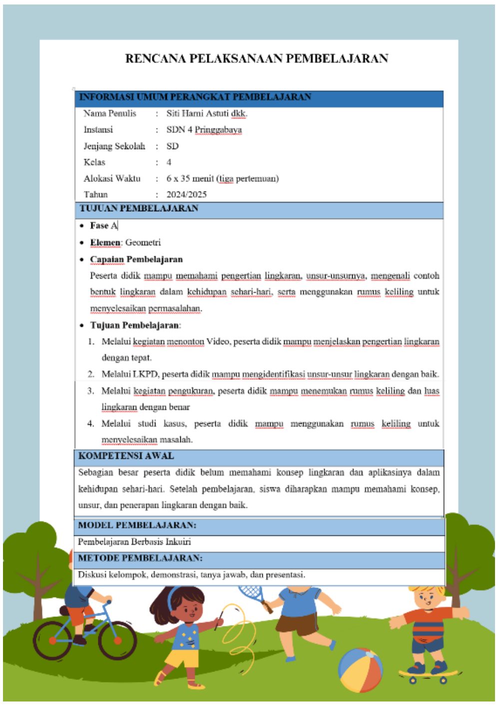
Design Stage

The design stage in this study was carried out to produce an initial draft of an inquiry-based learning device that is systematic and aligned with the objective of enhancing students’ interest and conceptual understanding in mathematics. This process began with the activity of criterion-test construction, which involved the development of two types of evaluation instruments. First, a conceptual understanding test was created in the form of open-ended essay questions aimed at assessing students' conceptual abilities in accordance with the indicators of competency achievement. Second, a learning interest questionnaire was developed using a five-point Likert scale, covering dimensions such as attention, interest, engagement, and perseverance in learning mathematics. Both instruments were constructed based on relevant theories and underwent expert review to ensure content validity and alignment with instructional objectives. In addition, at this stage, a teacher response questionnaire was also developed to collect data on the practicality of the learning device.

Subsequently, during the media selection stage, learning media were carefully considered to support an active and exploratory inquiry-based learning process. The selected media included an inquiry-based Student Worksheet (Lembar Kegiatan Peserta Didik or LKPD) designed to guide students through a series of concept-discovery activities, concrete teaching aids and visual illustrations to help visualize abstract concepts, as well as interactive presentation media such as PowerPoint to introduce contextual phenomena that stimulate students’ curiosity. The selection of media was based on considerations of accessibility, school context, and effectiveness in encouraging active student participation.

In the next stage, format selection, the structure and presentation of the learning materials were determined to ensure alignment with inquiry-based approaches and constructivist learning principles. The format of the Lesson Plan (Rencana Pelaksanaan Pembelajaran or RPP) was designed using the inquiry syntax, consisting of five main steps: problem orientation, problem formulation, hypothesis generation and testing, data collection and analysis, and conclusion drawing. Meanwhile, the LKPD format was developed with exploratory columns that encouraged students to observe, record hypotheses, engage in group discussions, and independently formulate conclusions. The evaluation instruments were also arranged systematically, accompanied by appropriate scoring rubrics to assess both the process and learning outcomes.

As the final product of the design stage, an initial design was developed in the form of a prototype learning device, which includes inquiry-based lesson plans (RPP), contextual LKPDs designed to foster active learning experiences, a teacher response questionnaire, and evaluation instruments. All components were cohesively designed to promote students' cognitive and affective engagement in mathematics learning. The visual excerpts of the designed product can be seen in Figures 2 and 3.



RENCANA PELAKSANAAN PEMBELAJARAN

INFORMASI UMUM PERANGKAT PEMBELAJARAN

Nama Penulis : Siti Harni Astuti dkk.
Instansi : SDN 4 Pringgabaya
Jenjang Sekolah : SD
Kelas : 4
Alokasi Waktu : 6 x 35 menit (tiga pertemuan)
Tahun : 2024/2025

TUJUAN PEMBELAJARAN

- **Fase** A
- **Elemen**: Geometri
- **Capaian Pembelajaran**
  Peserta didik mampu memahami pengertian lingkaran, unsur-unsurnya, mengenali contoh bentuk lingkaran dalam kehidupan sehari-hari, serta menggunakan rumus keliling untuk menyelesaikan permasalahan.
- **Tujuan Pembelajaran**:
  1. Melalui kegiatan menonton Video, peserta didik mampu menjelaskan pengertian lingkaran dengan tepat.
  2. Melalui LKPD, peserta didik mampu mengidentifikasi unsur-unsur lingkaran dengan baik.
  3. Melalui kegiatan pengukuran, peserta didik mampu menemukan rumus keliling dan luas lingkaran dengan benar
  4. Melalui studi kasus, peserta didik mampu menggunakan rumus keliling untuk menyelesaikan masalah.

KOMPETENSI AWAL

Sebagian besar peserta didik belum memahami konsep lingkaran dan aplikasinya dalam kehidupan sehari-hari. Setelah pembelajaran, siswa diharapkan mampu memahami konsep, unsur, dan penerapan lingkaran dengan baik.

MODEL PEMBELAJARAN:

Pembelajaran Berbasis Inkuiri

METODE PEMBELAJARAN:

Diskusi kelompok, demonstrasi, tanya jawab, dan presentasi.

Figure 2. Screenshot of the Lesson Plan (RPP) Design

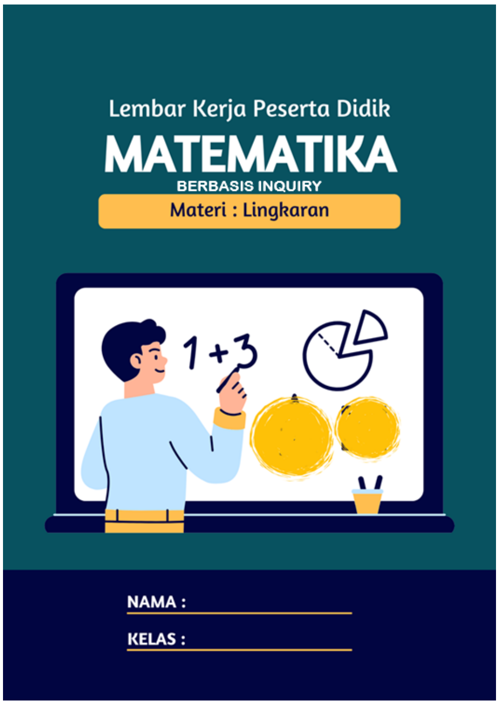


Figure 3. Screenshot of the Student Worksheet (LKPD)

Develop Stage

In the develop stage, the designed instructional materials were validated, revised, and then tested in real classroom situations. The aim of this stage was to ensure that the inquiry-based learning tools developed met the criteria of practicality and effectiveness in enhancing students' learning interest and mathematical conceptual understanding. The results obtained are outlined as follows:

Validation results of the learning tools

The validation process was conducted by two experts: a mathematics subject-matter expert and an elementary education expert. The results of the validation are summarized in Table 6. Validation results indicated that all components of the instructional tools were categorized as very valid, making them eligible to proceed to the field trial stage. Suggestions and comments from the validators were used to revise and refine several parts of the materials. These inputs were minor in nature and focused on technical improvements.

Tabel 6. Recapitulation of Validation Results of Instructional Materials

Instrument	Validator	Scores			%	Criteria
		Obtained	Average	Max		
Lesson Plan	Validator 1	94	92	96	95.83	Very Valid
	Validator 2	90				
Student Worksheet	Validator 1	70	68.5	72	95.14	Very Valid
	Validator 2	67				
Teacher Response Questionnaire	Validator 1	58	56	60	93.33	Very Valid
	Validator 2	54				
	Validator 1	62	61	64	95.31	Very Valid

Instrument	Validator	Scores			%	Criteria
		Obtained	Average	Max		
Learning Interest Questionnaire	Validator 2	60				
Conceptual Understanding Test	Validator 1	59	58.5	60	97.50	Very Valid
	Validator 2	58				

For the Lesson Plan (RPP), the validator recommended revising the formulation of the learning objectives to be more specific and operational using the ABCD format (Audience, Behavior, Condition, Degree). Regarding the Student Worksheet (LKPD), no revisions were suggested. For the Learning Interest Questionnaire, it was advised to simplify some terms to enhance comprehension for elementary school students. As for the Teacher Practicality Questionnaire, the validator suggested adding an item that evaluates the ease of assessing students' conceptual understanding. Meanwhile, the Conceptual Understanding Test was approved without any revisions.

Field Trial Results of the Instructional Materials

The field trial was conducted after the inquiry-based instructional materials were validated by experts. The trial took place at SDN 4 Pringgabaya. The research subjects were 26 students from Class IVA. The learning activities were carried out over four instructional sessions and one evaluation session. The purpose of this trial was to obtain empirical data on the practicality of the instructional materials, students' learning interest, and their conceptual understanding of mathematics following the implementation of the developed materials.

Practicality

Practicality data were obtained through a teacher response questionnaire and classroom implementation observations. The teacher completed the questionnaire after conducting all phases of instruction using the inquiry-based learning materials. The results indicated a practicality score of 86.67%, which falls into the "very practical" category. The teacher stated that the materials were easy to use, provided clear instructions, aligned well with the allocated instructional time, and effectively facilitated students' active learning. Furthermore, observation results confirmed that each phase of the inquiry learning model was successfully implemented, with high levels of student engagement at every stage.

Furthermore, the researcher conducted an interview with the teacher who used the learning tools in this study. Below is an excerpt from the interview regarding the practicality of the learning tools that were trialed:

Researcher : *Good morning, Madam teacher. Thank you for taking the time to talk with us about the learning tools developed in this study. We would like to hear your opinion about the practicality of these tools in mathematics learning in early-grade classrooms. First of all, what do you think about the structure and format of these learning tools?*

Teacher : *Good morning, thank you for inviting me. Overall, I feel that the structure of this learning tool is quite clear and easy to understand. The format is also well-organized, so I can follow the steps without difficulty. The student worksheets*

(LKPD) are simple and easy to use, especially in facilitating students to explore and solve problems using an inquiry approach. The learning steps are also quite systematic, from observation to drawing conclusions.

Researcher : That's great, Madam. Is this tool easy to use in daily classroom activities? Are there any difficulties or challenges you encountered while using this tool?

Teacher : Overall, I feel this tool is quite easy to use. However, there are some challenges I faced, especially when trying to ensure that all students can follow the inquiry process properly. Some students understand more quickly, while others need more time to think and find solutions. Nevertheless, this tool provides many opportunities for discussion and group work, which helps them understand mathematical concepts more deeply. I think for some students who need more time, the material could be slightly slowed down.

Researcher : Can this tool support increased student interaction, such as group discussions or collaboration in learning?

Teacher : Yes, I see that this tool greatly supports collaboration in the classroom. Students are more active in discussing within groups while working on the LKPD. They share ideas with each other, which makes the learning atmosphere more interactive. This approach encourages students to think critically and express their opinions. This is very helpful, especially in facilitating students who are usually more passive in learning.

Researcher : What is your opinion on the effectiveness of this tool in enhancing students' understanding of the circle material taught?

Teacher : I feel this tool is quite effective in helping students understand the concept of circles. By using the inquiry approach, students understand the concept through exploration activities and direct application. They are not just listening to theory, but also engaging in activities that allow them to discover the relationships between concepts. For example, when they create a circle model or calculate its circumference and area, they can more easily understand how the formula is applied in real life.

Researcher : Finally, does this learning tool provide benefits in terms of developing students' learning interest?

Teacher : In my opinion, this tool is very helpful in increasing students' interest in mathematics. Students become more interested in learning because they can see the direct application of the concepts being studied, and the learning becomes more enjoyable. The inquiry approach used makes them more active and enthusiastic about learning, which is certainly very positive for mathematics learning in early-grade classrooms.

Based on the interview results, it can be concluded that the inquiry-based learning tools are considered practical and effective for use in early-grade mathematics instruction. The teacher stated that the structure and format of the tools are clear, systematic, and easy to use, including the student worksheets (LKPD) that facilitate exploration and problem-solving processes. Although challenges were encountered in adjusting to students' varying learning speeds, the tools still promote student interaction and collaboration through active group discussions. The inquiry approach is seen as capable of enhancing conceptual understanding, especially on the topic of circles, as students can more easily grasp the application of formulas through hands-on activities. Moreover, the tools are also effective in fostering students' interest in learning mathematics, making the learning experience more enjoyable and meaningful. Overall, the tools make a positive contribution to improving students' understanding and engagement in mathematics learning.

Students' Learning Interest

Students' learning interest was measured using a learning interest questionnaire administered before and after the instructional intervention. After analysis, a summary of students' learning interest scores is presented in Table 7.

Table 7. Recapitulation of Students' Learning Interest Data

No	Categori	Number of Student	Persentase (%)
1	Very high	23	88.46
2	High	3	11.54
3	Moderate	0	0.00
4	Low	0	0.00
5	Very Low	0	0.00
	Total	19	**100,00**

Based on Table 7, the percentage of students who reached the "very high" category exceeded 75%. This indicates that the inquiry-based learning implemented through the developed instructional materials was effective in increasing students' interest in learning mathematics. The improvement in students' learning interest also can be observed in Figure 4.

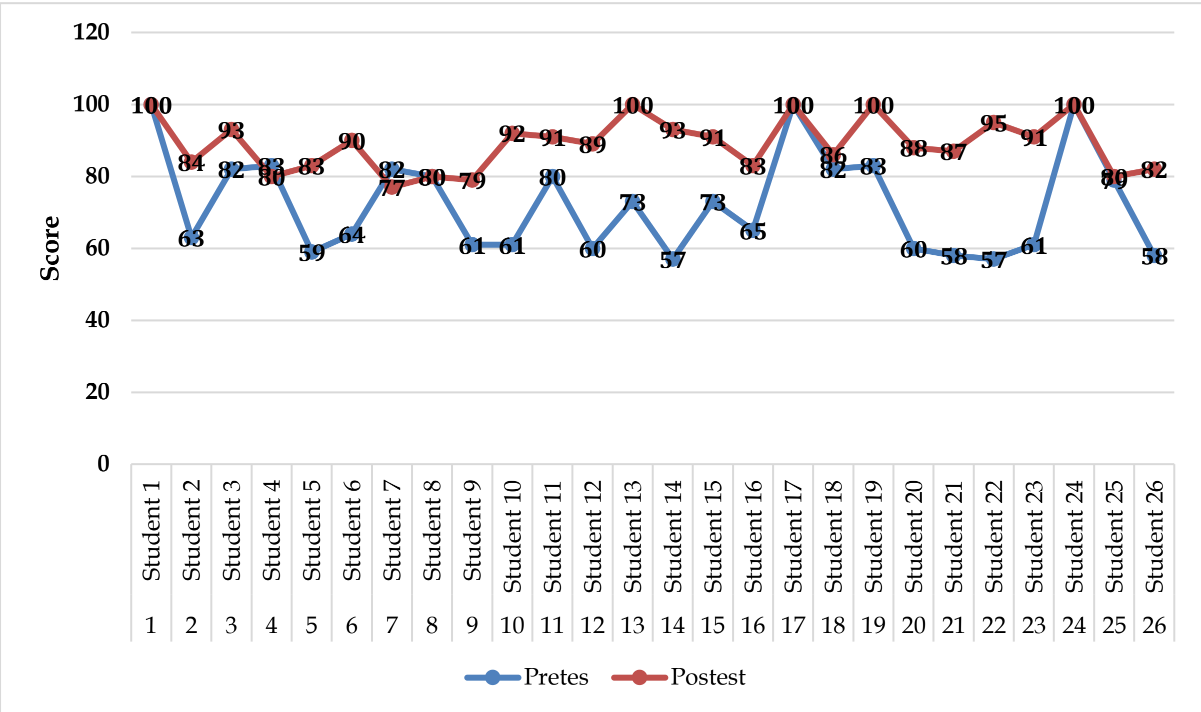


Figure 4. The improvement of students' Interest in learning mathematics

Figure 4 presents a diagram of improving students' interest in learning mathematics based on pretest and posttest scores. the blue line represents the pretest scores, while the orange line shows the posttest scores after the implementation of the inquiry-based learning tools. It is evident that the posttest scores are consistently higher than the pretest scores for nearly all students. This increase reflects a general improvement in learning interest across most participants. The pattern indicates that the applied learning approach successfully stimulated students' enthusiasm and engagement in the mathematics learning process. This improvement also suggests that students became more motivated and interested in learning after participating in a learning experience that emphasizes exploration and active interaction.

Mathematical Conceptual Understanding

Based on the results of the data analysis, the average pretest score was 19.04, while the average posttest score increased significantly to 76.73. The average posttest score was considerably higher than the pretest score. Furthermore, the results of the analysis on students' learning mastery are presented in Figure 5.

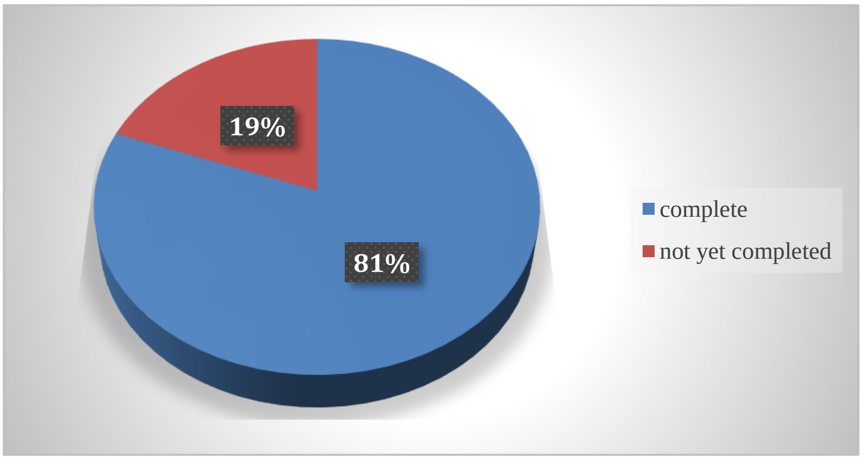


Figure 5. Students' mathematical conceptual understanding

Based on the pie chart presented in Figure 5, the data on students' mathematical conceptual understanding indicates that the majority of students achieved mastery learning. Figure 3 presents the distribution of students' conceptual understanding levels in mathematics following the implementation of the inquiry-based learning tools. According to the data, 81% of students successfully achieved complete conceptual understanding, indicating that the developed learning tools were effective in facilitating meaningful comprehension through guided inquiry and exploration processes.

There is a problem, 19% of students did not reach mastery in understanding the taught concepts. This lack of mastery can be attributed to several factors. First, some students struggled with grasping the abstract nature of the concepts and applying formulas accurately. Second, certain students were not yet able to develop systematic problem-solving strategies. Third, there were slow learners who required more time, concrete approaches, and repeated exposure to the material. In addition, some students demonstrated low self-confidence and passive participation in group discussions.

Importantly, several students were unfamiliar with the inquiry-based learning approach, which demands exploration, initiative, and independent conclusion-making. This group may require additional support in the form of learning assistance or more flexible study time to build comprehensive understanding. These findings highlight the initial effectiveness of the developed learning tools while also providing valuable insights for further refinement, ensuring equitable achievement of learning outcomes among all students. Nevertheless, the research findings indicate that all students experienced an increase in scores from the pretest to the posttest. This result can be seen in Figure 6.

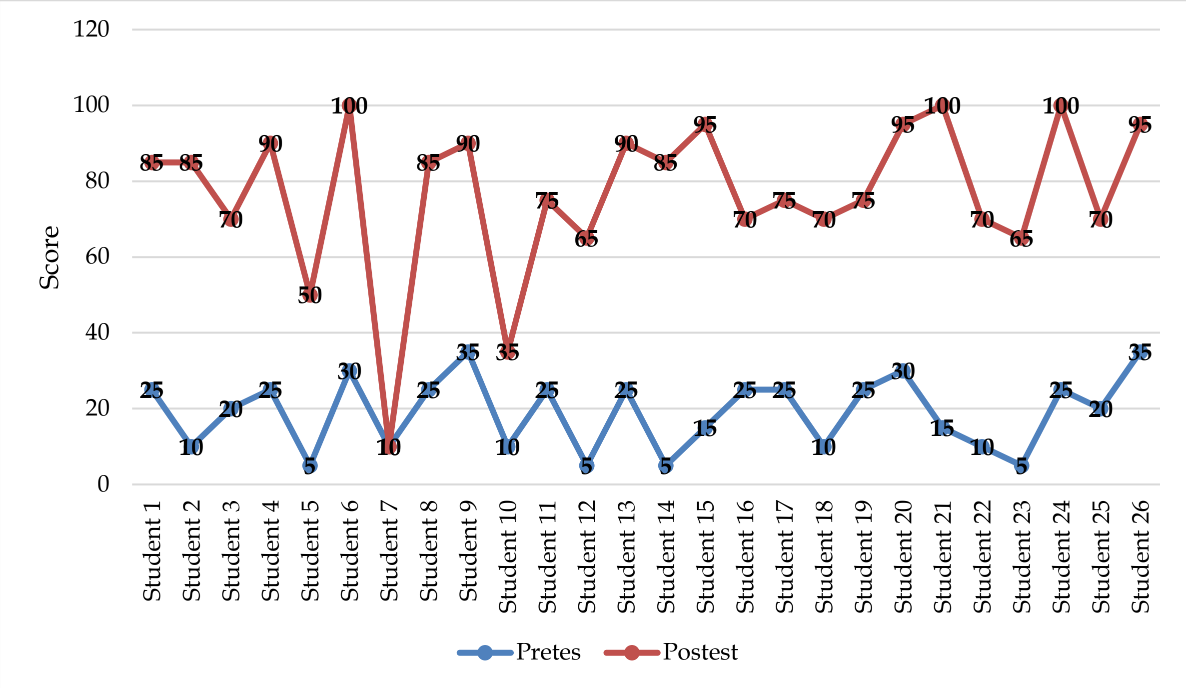


Figure 6. The improvement of students' mathematical understanding

Figure 6 illustrates the improvement in pretest and posttest scores of 26 students in understanding mathematical concepts after participating in inquiry-based learning. It is evident that the posttest scores are consistently higher than the pretest scores. This pattern indicates that the inquiry-based learning approach effectively enhances students' conceptual understanding, particularly on the topic of circles, which includes elements of a circle, formulas for circumference, and their application in problem-solving. Furthermore, based on the results of the N-GAIN test using SPSS, the results are shown in Table 8.

Table 8. Result of N-Gain Test

	N	Minimum	Maximum	Mean	Std. Deviation
NGain	26	.00	1.00	.7166	.25572
NGain_%	26	.00	100.00	71.6555	25.57205
Valid N (listwise)	26				

Table 8 presents the results of the N-Gain test on the improvement of students' conceptual understanding in mathematics after participating in inquiry-based learning. From the 26 students who were sampled, the average N-Gain score was 0.7166 with a standard deviation of 0.25572. When converted into percentage form, the average N-Gain reached 71.6555% with a standard deviation of 25.57205. The minimum N-Gain value was 0.00, and the maximum was 1.00, indicating a variation in the level of improvement among students. Based on the gain criteria interpretation, an N-Gain value of 0.71 falls into the high category. This indicates that, overall, the participants showed a significant improvement in their understanding of the material after the intervention. These findings indicate that the inquiry-based learning approach, implemented through the developed instructional materials, was effective in improving students' conceptual understanding of mathematics.

The validation and field testing of the materials confirm that the inquiry-based instructional tools developed in this study met the standards of feasibility and practicality. These results reinforce the idea that the successful implementation of the inquiry syntax during the trial reflects the materials' effectiveness in integrating the principles of active and constructivist learning, which are essential in mathematics education. Students' active participation throughout the implementation further demonstrates that inquiry-based learning not only enhances conceptual understanding but also increases motivation and engagement in the learning process (Chalimi, 2023; Yusnita & Astriani, 2022). Thus, it can be concluded that the developed instructional materials are both practical and effective in improving students' interest and conceptual understanding in mathematics.

Dissemination Stage

The dissemination stage in this study was carried out as an initial effort to distribute the inquiry-based instructional materials that had been developed. In this research, a large-scale field trial was not conducted due to limitations in time, resources, and testing scope. However, several dissemination activities were undertaken as preliminary steps toward broader utilization. These dissemination activities were implemented through several strategies: the publication of the research report as academic documentation; the archiving of instructional materials in the library of SDN 4 Lombok Barat to be used by other teachers as a reference for teaching and learning activities; and the publication of research findings in an accredited national journal to reach a wider audience of academics and educational practitioners.

These efforts aimed to evaluate the initial acceptance of the product by early users and simultaneously serve as a means to obtain constructive field feedback. As emphasized by Suwanto and Lestari (2024), involving end-users in the product refinement process is essential to ensure the relevance and sustainability of instructional materials across various educational contexts.

Based on the research findings that have been described, it can be concluded that the developed instructional materials meet the criteria of being valid, practical, and effective in enhancing students' interest and learning outcomes in mathematics. The research process also revealed several significant findings related to the improvement of students' interest and conceptual understanding in mathematics. The implementation of the inquiry-based learning model had a notable impact on enhancing students' learning interest and conceptual understanding through a set of interconnected and systematic stages.

This study has limitations. We recognize that the sample size, consisting of only 26 students, may limit the generalization of the findings. The sample size does not reflect the entire population of students at a broader level. Therefore, although the results show a significant improvement in students' learning interest and conceptual understanding of mathematics, we must be cautious in generalizing these findings to a larger population without further research with a more representative sample.

Additionally, we acknowledge that this study did not use an experimental design with a control group, which would allow for a direct comparison between the group using this learning tool and the group not using it. The absence of a control group is a methodological limitation that could affect the interpretation of the effectiveness of the learning tools. Therefore, while the results obtained show positive improvement, conclusions regarding the effectiveness of this learning tool should be viewed with caution. It is recommended that further research use a stronger experimental design, such as a control group, and a larger sample size to obtain more convincing evidence.

In the problem orientation stage, students were introduced to relevant contextual problems, which stimulated their curiosity and interest in the subject matter. This stage also helped construct an initial conceptual framework by presenting real-life situations that captured their attention. This finding is in line with previous studies, which emphasize that this stage is crucial in encouraging students to explore and understand the relationships between the concepts being taught and real-world situations (Aditomo & Klieme, 2020; Anjani et al., 2018). Through contextual problems, students are not merely recipients of information but are also encouraged to formulate relevant questions, which enhances their engagement (Verawati et al., 2020).

Subsequently, in the problem formulation stage, students were actively involved in designing questions or problems they wished to solve. This activity enhanced student engagement and developed their critical thinking skills in identifying key concepts relevant to mathematical problems. This is in line with research indicating that students' active participation in formulating questions and hypotheses through the inquiry approach can improve their self-confidence and learning initiative (Mao, 2023; Putri Lisa et al., 2023). At this stage, students' critical thinking skills developed significantly as they were engaged in the problem-solving process in a more active and reflective manner Xie, (2023).

The hypothesis formulation stage encouraged students to propose initial predictions of possible solutions, which had a positive effect on their enthusiasm and confidence. Conceptually, this stage trained students to logically and systematically link prior knowledge to new contexts. As they entered the data or information collection stage, students’ learning interest was further stimulated through exploratory activities such as observation, discussion, or experimentation. This active engagement enabled students to construct meaningful conceptual understanding by experiencing the learning process firsthand.

Once data had been collected, students proceeded to the hypothesis testing stage, where they compared their observations with their initial assumptions. This process presented an intellectual challenge and triggered a sense of learning satisfaction that reinforced their understanding, as they learned through verification and reflection. This is consistent with the views of Pratiwi et al., (2019) and Apriani et al., (2022), who noted that involvement in data collection is also a crucial step in inquiry-based learning. Students engaged in exploratory activities such as observation and experimentation, which deepened their conceptual understanding and provided them with better insights into the learning process. One relevant aspect of inquiry-based learning is the hypothesis testing process, in which students evaluate their observations against their prior predictions. This process not only poses intellectual challenges but also enhances students’ satisfaction and confidence in their ability to interpret data and draw conclusions (Hikmawati, 2018; Koksalan & Ogan-Bekiroglu, 2024).

The final stage, drawing conclusions, is a key moment for students to synthesize their understanding of the learned concepts. At this stage, students not only integrate the information obtained throughout the learning process but also communicate it, both orally and in written form, thereby solidifying and structuring their conceptual comprehension. Overall, inquiry learning encourages students to actively engage in learning, enhances their interest at every stage, and builds mathematical conceptual understanding through a structured scientific and reflective thinking process. When students reach the final stage—drawing conclusions—they are expected to synthesize all the information they have acquired and communicate it coherently, both verbally and in writing. This process is intended to strengthen their understanding of the concepts learned Aristeidou et al., (2020).

Inquiry-based learning (IBL) has a significant impact on students' cognitive and affective development, particularly in enhancing active engagement and intrinsic motivation. The IBL model is based on the Inquiry-Based Learning Theory of John Dewey and Jerome Bruner, which emphasizes students' active involvement through exploration and discovery of knowledge. Dewey stated that effective learning occurs when students have the opportunity to ask questions and learn from direct experiences (Chen, 2023), while Bruner highlighted the importance of the discovery process in building knowledge (Tzuo, 2007). This approach facilitates students in constructing knowledge independently, which improves their conceptual understanding. Furthermore, the Constructivist Theory introduced by Jean Piaget and Lev Vygotsky complements inquiry theory by emphasizing how students construct knowledge through experiences and social interactions (Aeni et al., 2023; Arega & Hunde, 2025). Piaget emphasized assimilation and accommodation in students' cognitive development, while Vygotsky stressed the role of social interaction in the zone of proximal development, which allows students to learn more effectively with the help of others (Arega & Hunde, 2025).

By combining these theories, the IBL model supports both cognitive and affective student engagement in the learning process. Inquiry-based learning provides students the freedom to explore subject matter, enhances their intrinsic motivation, and encourages them to think more critically and creatively. Through exploration and discovery experiences, students can link new concepts to existing knowledge, thus building more flexible and lasting cognitive structures. As such, this model not only deepens conceptual understanding but also enhances learning interest and higher-order thinking skills, which are essential in education. The integration of inquiry and constructivist theories provides a profound framework for the cognitive and affective development of students, enriching their learning experience (Aeni et al., 2023; Arega & Hunde, 2025).

Inquiry-based learning not only increases students' interest in learning mathematics but also fosters a deeper understanding of the taught concepts. The structured scientific and reflective thinking process enables students to develop essential 21st-century skills, such as critical and creative thinking (Kožuchová et al., 2022; Wang et al., 2020). Research indicates that the inquiry approach has a significantly positive impact on both learning outcomes and overall student engagement (Roys et al., 2023;Verawati et al., 2020).

Although the development of inquiry-based learning tools in this study was designed with the local context of Lombok in mind, the approach holds strong potential for replication and adaptation across various educational settings in other regions. The contextual approach employed is flexible and can be tailored to the unique characteristics of learning environments throughout Indonesia, as long as it maintains the core principles of inquiry-based learning, which emphasize active student engagement, exploration, and independent knowledge construction. Furthermore, these learning tools have the potential to be integrated into the implementation of the *Kurikulum Merdeka*, which promotes meaningful, differentiated learning based on students' needs and contextual backgrounds. Thus, this learning model is not only relevant for the local context but can also make a strategic contribution to improving the quality of mathematics education at the national level. The potential for replication opens opportunities for further research and the development of broader educational policies, particularly in mainstreaming inquiry-based approaches as a key instructional strategy in elementary education in Indonesia.

CONCLUSION

Based on the results and discussion of the study, it can be concluded that the inquiry-based mathematics instructional materials developed in this research have proven to be valid, practical, and effective in enhancing students' learning interest and conceptual understanding. The validity of the materials was confirmed through expert evaluations, which indicated alignment with pedagogical principles, content appropriateness, and technical feasibility. Practicality was evidenced by teacher response questionnaires, which showed that the materials were easy to use and facilitated smooth classroom implementation. Meanwhile, effectiveness was reflected in the improvement of students' learning interest—seen in indicators such as curiosity, enthusiasm, engagement, and interest—as well as in their increased conceptual understanding.

RECOMMENDATIONS

As a follow-up to this study, it is recommended that teachers consistently implement the inquiry-based learning model in mathematics instruction, particularly for topics that require a high level of conceptual understanding. Teachers should design inquiry activities that are challenging yet developmentally appropriate, and that encourage active student involvement through discussion, exploration, and reflection. For future researchers, it is suggested to explore the implementation of the inquiry model at other educational levels or in different mathematical topics to examine the generalizability of the model's effectiveness. Furthermore, the development of inquiry-based instructional materials equipped with implementation guidelines is also necessary to facilitate ease of use for teachers in the field.

This study has limitations, including a small sample size, consisting of only 26 students, which restricts the ability to generalize the findings to a broader population. Additionally, this study did not use an experimental design with a control group, so there was no direct comparison between the group using the learning tools and the group not using them, which could affect the interpretation of the effectiveness of the tool. For future research, it is recommended to use a stronger experimental design with a control group and to increase the sample size to enhance the generalizability of the findings.

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All authors have read and agreed to the published version of the manuscript.

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Conflict of interests
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