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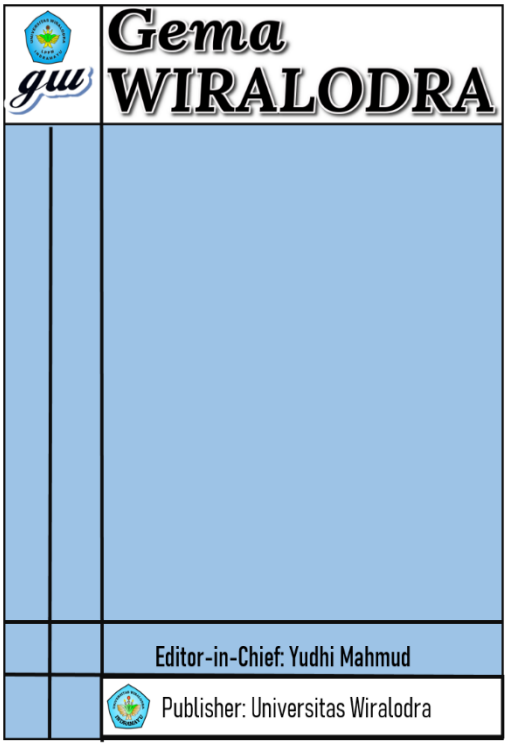

Development of learning tools using an open-ended approach with questions and higher-order thinking skills to improve students' mathematical reasoning abilities

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Development of learning tools using an open-ended approach with questions and higher-order thinking skills to improve students' mathematical reasoning abilities

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Abstract
Mathematical reasoning abilities were crucial for comprehending mathematical concepts and equipping students to confront the challenges of the 21st century. However, the persisting issue of students' inadequate mathematical reasoning abilities remained relevant. Hence, this study aimed to assess the efficacy and practicality of educational tools utilizing an open-ended approach with HOTS (higher-order thinking Skills) questions to enhance students' mathematical reasoning capabilities. The research employed the research and development (R&D) method, involving students from Madrasah Tsanawiyah (MTs) Istiqlal Jakarta and expert educators. This developmental study followed the ADDIE model, encompassing analysis, design, development, implementation, and evaluation stages. The research tools included observation sheets for monitoring the learning process, expert assessment questionnaires to evaluate tool suitability, student response surveys, and mathematical reasoning proficiency assessments to gauge tool effectiveness. Findings indicated the feasibility of employing learning tools with HOTS questions and an open-ended approach to enhance students' mathematical reasoning skills, with an average feasibility rate of 89%. Evaluation by validators revealed a 96% average rating, signifying the learning tools' substantial validity for educational use. Furthermore, field trial results demonstrated that 89.29% of students achieved scores surpassing the minimum completeness criteria (MCC) post-tool implementation, affirming its efficacy in enhancing students' mathematical learning capacities. This research suggested that leveraging learning tools with HOTS questions and an open-ended approach presented new avenues for significantly bolstering students' mathematical reasoning skills. This underscored the importance of embracing innovative methodologies in crafting educational materials to foster more captivating and meaningful student-learning encounters.
Keyword(s): Higher-order thinking skills (HOTS), learning media, mathematical reasoning; Open-ended approach.

1. Introduction

Mathematical reasoning is considered a very important ability in understanding mathematical concepts, concluding statements, building new ideas, and solving mathematical problems (Nababan, 2020). Without reasoning abilities, mathematics will only be material that follows a series of procedures without deep understanding (Linola et al., 2017). Reasoning abilities are not only important in the context of mathematics learning but also have a broad, long-term impact on a person's daily life and career (Fatihah et al., 2023; Sudirman et al., 2022). This ability helps a person become more skilled and wiser and face challenges better.

Unfortunately, problems often occur related to students' mathematical reasoning abilities. One of the main problems is students' lack of ability to apply mathematical reasoning effectively in problem-solving (Szabo et al.,2020). Students often have difficulty identifying problems, formulating problem-solving strategies, and making valid mathematical justifications for the solutions they find. Students' weak mathematical reasoning abilities can

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be caused by a lack of practice in dealing with mathematical problems that require high-level reasoning. Students' low mathematical reasoning abilities have been identified in various studies (Nababan, 2020; Ariati & Juandi 2021; Wau et al., 2022). Likewise, according to the TIMSS 2023 study results, Indonesia is ranked 68th out of 79 participating countries with an average score of 375. The TIMSS 2023 results show that the reasoning abilities of Indonesian students are still low. In the reasoning domain, Indonesian students could only answer 17% of the questions given. This shows that Indonesian students still have difficulty understanding mathematical concepts, applying these concepts to solve problems, and drawing conclusions from the problem-solving results.

In an era of education that continues to develop, emphasis on higher-order thinking skills (HOTS) is becoming increasingly important to prepare students to face the challenges of the 21st century. HOTS includes higher-order thinking skills such as analysis, evaluation, synthesis, and creativity, essential for solving complex problems and adapting to rapid changes in the modern world. However, implementing HOTS in the learning process often encounters obstacles, especially in developing appropriate learning tools to stimulate these abilities. The quality of learning tools used by teachers is still not good (Pattimura et al, 2020). Therefore, the development of teaching materials is becoming increasingly important, considering the need to adapt the curriculum to current developments and demands of technological progress. Quality teaching materials not only present material holistically but also pay attention to the diversity of student learning styles and facilitate the development of necessary critical and reasoning skills. As Novandi & Firmansyaha (2018) say, problem-based teaching materials developed with modified 4-D models are effective for mathematical reasoning and connection abilities.

In developing teaching materials that emphasize higher-order thinking Skills (HOTS), an open-ended approach becomes relevant to consider. An open-ended approach allows students more space to explore their ideas and create unique and original answers. Students must analyze, evaluate, and construct arguments critically in solving open-ended problems, thereby helping improve their critical thinking skills (Ali, 2019; Susandi & Sudirman, 2024). By using this approach, learning tools can be designed so that students are not only asked to give right or wrong answers but also to think critically, analytically, and creatively. For example, an open-ended approach can be used in teaching mathematics to construct problems that ask students to find possible solutions to a given problem rather than simply evaluating predetermined answers. This will stimulate students to think more deeply and creatively about the mathematical concepts they are learning.

This research presents novelty by proposing the integration of an open-ended approach with the use of HOTS questions, offering an innovative combination that stimulates students' reasoning abilities. The strong focus on reasoning abilities responds to educational needs in facing the challenges of the 21st century. At the same time, the development of creative and innovative learning tools makes a valuable contribution to learning practices in the field. By emphasizing relevance to the demands of the 21st century, this research not only expands the understanding of effective learning approaches in improving students' reasoning abilities but also provides new insights into designing relevant and meaningful learning tools for the future of education.

2. Method

The research design used in this research was research and development (R&D) because this research aimed to produce certain products and test the validity and effectiveness of these products in their application. In this research, the product produced was a learning tool using an open-ended approach with HOTS questions to improve students' mathematical

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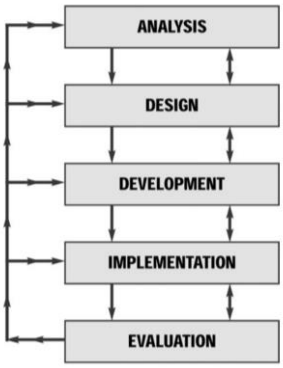
reasoning abilities. The resulting learning tools included learning modules, student worksheets, and mathematical reasoning ability tests. The R&D model used was the ADDIE model as proposed by Molenda (2015) with five steps, namely 1) Analysis, 2) Design, 3) Development, 4) Implementation, and 5) Evaluation. The ADDIE model was often favored as a method for educational research and development because several reasons such as ADDIE provided a systematic framework that covers all stages of instructional design, from initial analysis to final evaluation, it also allows for flexibility and adaptation to different contexts and needs, it also allowed for flexibility and adaptation to different contexts and needs. While ADDIE had many advantages, it was essential to note that other research methods and models also had their strengths and might be more suitable depending on the specific goals and requirements of a research project. Here is the flowchart of this research (See Figure 1).

Figure 1

Flowchart of R&D Research Steps



The analysis stage was the stage of analyzing teaching materials and requirements in development. At this stage, three things were carried out: needs analysis, curriculum analysis, and student character analysis. At the design stage, instruments were prepared to assess learning tools as well as instruments to test mathematical reasoning abilities. At the development stage, learning tools began to be developed using HOTS questions according to the design. All instruments and learning tools were validated and tested at this stage. The implementation phase was carried out in a limited manner at the school designated as the research site. Researchers conducted learning with an open-ended approach by applying teaching materials using HOTS questions that had been developed. Observations were carried out to see the learning process and improve learning tools. Before learning, students were given a pretest, and after learning, students were given a posttest. At this stage, a response questionnaire was given to obtain data related to the practical value of using the product. The evaluation stage was to revise the final learning tools developed based on response questionnaires or field notes on observation sheets. This revision aimed to ensure that the teaching materials using the HOTS questions developed were truly appropriate and could be used by a wider range of schools.

The research subjects were MTs Istiqlal Jakarta students and expert lecturers. The object of this research was the feasibility of developing teaching materials using HOTS questions to improve students' mathematical reasoning abilities. Students became sources in obtaining data on teaching material needs using HOTS questions, expert lecturers became data sources in assessing and improving teaching materials using HOTS questions, and trials of teaching materials using HOTS questions with an open-ended approach were carried out on students.

Data collection was carried out through observation, questionnaires, and tests. Observations were used to identify problems and observe student learning before and after implementing teaching materials using HOTS questions with an open-ended approach. There

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were 3 types of questionnaires used in this research, namely expert assessment questionnaires to test the feasibility and practicality of learning tools and student response questionnaires regarding teaching materials. Tests were used to obtain results of students' mathematical reasoning abilities in learning. Data analysis was carried out descriptively and qualitatively which focused on the development of learning tools using an open-ended approach with HOTS questions involving a combination of quantitative and qualitative methods to evaluate the impact of the intervention on students' learning outcomes.

3. Result and Discussion

Research that has been conducted by several previous researchers relevant to this study includes: "The Relationship Between Self-Efficacy and Mathematical Reasoning Ability in Middle School Students" by Angel Mukuka, Védaste Mutarutinya, and Sudi Balimuttajjo. This journal was published in the Journal of Educational Psychology in 2022. This study was conducted to examine the relationship between self-efficacy and the mathematical reasoning ability of middle school students. The results of the study indicate that there is a significant positive relationship between self-efficacy and the mathematical reasoning ability of middle school students. Students with high self-efficacy tend to have better mathematical reasoning abilities than students with low self-efficacy.

The development of learning tool instruments with HOTS questions using an open-ended approach in learning Mathematics with Algebra material to improve students' mathematical reasoning abilities has gone through a series of development phases starting from the analysis, design, development, implementation, and evaluation to produce a product, namely a learning tool with HOTS questions using an open-ended approach in learning Mathematics with Algebra material to measure students' mathematical reasoning abilities.

The initial step in the research was to conduct a descriptive, exploratory needs analysis using a qualitative approach. The needs analysis uses interview and questionnaire techniques to describe teachers' needs in teaching and learning activities in Algebra material. The data sources are students and teachers of class VII MTs Istiqlal Jakarta. The analysis results show that teachers still use learning tools that are considered less interesting and innovative and still provide routine questions from textbooks. Even though the learning tools used by teachers are appropriate, they require exploration to make them more interesting. Teachers feel the need for learning tools, so they use an open-ended approach with HOTS questions to improve students' reasoning abilities, especially in Algebra material, which is considered difficult to find learning tools for. Based on this analysis, the teacher's hope for this learning tool is that it has clear instructions, the content of teaching materials is appropriate to Algebra material, problems are appropriate to students' cognitive level, and the use of language is by EYD rules (Kurniawati, et.al, 2020). Here is the product, which is Lembar Kerja Peserta Didik (LKPD) (Figure 2).

Figure 2
Examples of Learning Tools

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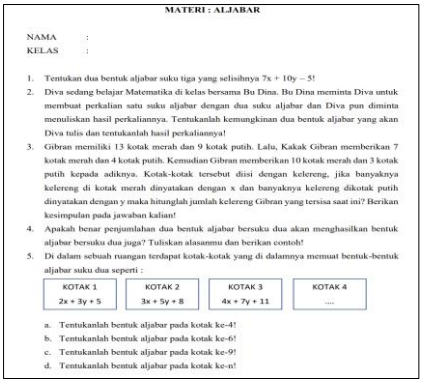

MATERI : ALJABAR

NAMA :
KELAS :

1. Tentukan dua bentuk aljabar suku tiga yang selisihnya 7x + 10y – 5!
2. Diva sedang belajar Matematika di kelas bersama Bu Dina. Bu Dina meminta Diva untuk membuat perkalian satu suku aljabar dengan dua suku aljabar dan Diva pun diminta menuliskan hasil perkaliannya. Tentukanlah kemungkinan dua bentuk aljabar yang akan Diva tulis dan tentukanlah hasil perkaliannya!
3. Gibran memiliki 13 kotak merah dan 9 kotak putih. Lalu, Kakak Gibran memberikan 7 kotak merah dan 4 kotak putih. Kemudian Gibran memberikan 10 kotak merah dan 3 kotak putih kepada adiknya. Kotak-kotak tersebut diisi dengan kelereng, jika banyaknya kelereng di kotak merah dinyatakan dengan x dan banyaknya kelereng dikotak putih dinyatakan dengan y maka hitunglah jumlah kelereng Gibran yang tersisa saat ini? Berikan kesimpulan pada jawaban kalian!
4. Apakah benar penjumlahan dua bentuk aljabar bersuku dua akan menghasilkan bentuk aljabar bersuku dua juga? Tuliskan alasanmu dan berikan contoh!
5. Di dalam sebuah ruangan terdapat kotak-kotak yang di dalamnya memuat bentuk-bentuk aljabar suku dua seperti :

KOTAK 1	KOTAK 2	KOTAK 3	KOTAK 4
2x + 3y + 5	3x + 5y + 8	4x + 7y + 11	....

a. Tentukanlah bentuk aljabar pada kotak ke-4!
b. Tentukanlah bentuk aljabar pada kotak ke-6!
c. Tentukanlah bentuk aljabar pada kotak ke-9!
d. Tentukanlah bentuk aljabar pada kotak ke-n!

After going through the analysis stage, the next step is to design learning tools with a similar approach, especially in Algebra material, which includes test grids, test questions, alternative test answers, and scoring guidelines. The initial stage includes designing HOTS test questions on Algebra material, which are designed based on analysis of Algebra material and indicators. Researchers designed several test questions that represent each material, with the criteria as a learning tool using an open-ended approach with HOTS questions and having indicators as mathematical reasoning questions. Next, the researcher compiled a test grid and alternative test answers based on the achievement indicators and cognitive domain of each question. In addition, researchers designed scoring guidelines to facilitate the assessment of test results on aspects of reasoning carried out by students, both by researchers, teachers and other parties involved.

The development stage aims to produce learning device products that have been revised based on input from experts (expert review) and data obtained from one-to-one trials. Activities at this stage include device validation by validators, followed by revisions and trials. The results of the activities at this development stage are as follows. Expert assessments are used as a basis for revising and improving learning tools. Instrument validation using learning tools is carried out by providing instrument validation sheets with test grids, test questions, alternative test answers and scoring guidelines to the validator. At the validation stage, the validator assesses the learning device instruments that have been designed. Each aspect assessed has a maximum value of 5 and a minimum of 1. A value of 1 means invalid, a value of 2 means less valid, a value of 3 means quite valid, a value of 4 means valid, and a value of 5 means very valid. Validators give an assessment above 90%, but there are several parts that need to be revised.

After being revised, the learning tools were tested on several class VII students at MTs Istiqlal Jakarta in a one-to-one trial. These students were three non-research trial subjects consisting of high, medium and low-ability students. After the teaching materials were tested on the three students, they were improved so that prototypes of 2 learning tools were produced and tested on a small group of non-research subjects consisting of 6 students. Students are asked to work on reasoning ability questions on Algebra material and are asked to provide comments on the HOTS questions and teaching materials they have worked on. Based on the students' comments, the learning tool uses an open-ended approach with HOTS questions on Algebra material followed by a field test. This process is as proposed by Li, et al (2020).

Implementation was carried out at MTs Istiqlal Jakarta class VII. The results of student observations in the algebraic mathematics learning process were analyzed using several assessment indicators related to changes in students' attitudes during learning activities. Aspects observed include: a) students listen to the teacher's explanation, b) students actively ask questions, c) students actively answer questions, d) students are active during the learning process, and e) students respond positively to teaching materials. Observation results

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show that learning Mathematics Algebra material using learning tools with HOTS questions using an open-ended approach obtained an average percentage of 89%. The average percentage value obtained reaches the expected target, namely 70%. Thus, learning tools can be said to be attractive to students. This is because students, during the process of teaching activities, pay close attention to the teacher's explanations, become more active in asking and answering questions, actively participate in learning activities, and respond positively to learning tools. In open-ended learning, there is a discussion stage where students can share opinions with other students and provide opportunities for other students to do the same. This allows students to be able to think at a high level mathematically and solve problems using complex procedures based on mathematical principles and ideas in a way that students can understand (Mulyawan et al, 2023).

At the evaluation stage, final revisions are made to the learning device products that have been developed from responses or notes in the field on observation sheets. The revised results from material expert validators, learning experts, and media experts related to learning tool instruments, from the three aspects assessed, show that material experts gave an average percentage assessment of 94%. Learning experts gave an average percentage rating of 96%. Media experts give an average percentage assessment of 98%. Thus, the average assessment of the three validators is 96%, which means it is greater than the set criteria, namely 70%. The percentage obtained by 96% shows that the learning device product with HOTS questions uses an open-ended approach developed in Mathematics learning Algebra material to improve students' mathematical reasoning abilities, which is included in the criteria of being suitable for use. The results of this research by Nourmaningtyas et al. (2020) show that teaching materials based on an open-ended approach are suitable for use as supporting teaching materials in mathematics learning to improve students' mathematical reasoning abilities. Furthermore, Nourmaningtyas et al. (2020) suggested that teachers should use one teaching material and other supporting teaching materials to support the primary teaching materials.

The effectiveness of learning device products can be seen from the results of data processing using the Paired Samples Test. Learning device products are said to be effective if they can significantly improve students' mathematical reasoning abilities. The calculation results are in Figure 3.

Figure 3

Paired Samples Test Results of Students' Reasoning Ability

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	SESUDAH - SEBELUM	38.000	15.473	2.924	32.000	44.000	12.996	27	.000

Based on the information obtained from the table, it can be concluded that students' reasoning abilities increased significantly from the pretest to the posttest after using the learning tools. The effectiveness of learning tools can also be seen in the students' MCC achievements, which are shown in Table 2.

Table 1

Percentage of Students' MCC Achievements in Mathematical Reasoning Ability

Student Achievements	Pretest		Posttest	
	Total	%	Total	%
< MMC	28	100	3	10.71
≥ MCC	0	0	25	89.29

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From the student score table, it can be seen that during the pretest, no students achieved an MCC score of 76. However, after implementing the learning tool with HOTS questions using an open-ended approach in learning Mathematics on Algebra material, there were 89.29% whose scores were above MCC. From this information, it can be concluded that learning tools using an open-ended approach based on HOTS questions are said to be effective. Apart from that, the N-Gain score obtained from the students' pretest and posttest results was 0.68, which shows a moderate increase approaching high (N-gain ≥ 0.7). The results of this research are in line with (Kurniawati et al., 2020). However, the results of Kurniawati's research on a mathematics module based on an open-ended approach can help improve students' high-level thinking skills (HOTS) in the material of systems of linear equations in two variables. Likewise, Lesmana (2018) concluded that the average value of students' mathematical reasoning abilities before using the open-ended approach was 54.54, which was in the "poor" category. Meanwhile, after using the open-ended approach, students' mathematical reasoning abilities reached an average score of 72.08, included in the "good" category.

Test the practicality of learning devices based on student responses. There are 15 indicators to assess practicality, and the average score is 89%. This shows that students' responses to learning tools with hot questions using an open-ended approach in improving mathematical reasoning abilities provide positive responses to students.

4. Conclusions

The process of developing learning tools with HOTS questions using an open-ended approach in learning mathematics Algebra material to improve students' mathematical reasoning abilities is carried out through 5 stages, namely: analysis, design, product development, implementation, and evaluation. The learning device products developed show significant effectiveness in improving students' mathematical reasoning abilities. This can be seen from the average value of students' mathematical reasoning abilities between the pretest and posttest scores as expected, namely that there is a significant difference (0.000 < 0.05). The effectiveness of the product is also demonstrated by the percentage of students achieving MCC of 89.29%. Then, the learning device product also shows its feasibility in improving students' mathematical reasoning abilities; this can be seen from the results of the feasibility test analysis based on very good student responses, showing an average response of 89%. The validity of the product was assessed by experts at 96%, which shows that the product is valid for use to improve students' mathematical reasoning abilities.

Based on the results of this research, teachers need to pay attention to student's needs and adapt learning tools with approaches that trigger higher-level thinking and mathematical reasoning abilities. Using an open-ended approach with HOTS questions can be an effective strategy for improving students' mathematical reasoning abilities. Training and support are needed for teachers to design and implement effective learning tools through HOTS questions to develop students' mathematical reasoning abilities.

The use of learning tools with HOTS questions and an open-ended approach to learning mathematics can significantly improve students' mathematical reasoning abilities. Learning design that pays attention to HOTS can help students become more skilled and ready to face the challenges of the modern world. This research provides a valuable contribution to learning practice in the field by demonstrating the relevance and effectiveness of using innovative approaches in improving students' mathematical reasoning abilities. Further research needs to be carried out to see the influence of certain factors, such as student learning motivation or the evaluation methods used, on the effectiveness of this learning tool.

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