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Development of guided discovery-based mathematics learning tools to enhance problem-solving skills in high school students

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Abstract

Background: Many students struggle with solving mathematical problems, which prevents them from achieving learning goals. To address this issue, this study develops learning tools designed to improve these skills.

Aim: The goal of this study is to create guided discovery-based mathematics learning tools that are valid, practical, and effective in enhancing students' problem-solving abilities.

Method: This study uses the Plomp development model, which includes three main stages: the initial investigation, development, and evaluation phases. The focus of this research is on the development of modules and student worksheets (LKPD).

Results: The validity of the products was assessed by experts in terms of content, language, and presentation, all of whom found the products to be valid and ready for use. The practicality of the tools was confirmed through feedback from both students and teachers, showing that they are very practical. The effectiveness of the tools in improving problem-solving skills was high, with an effectiveness score of 0.749.

Discussion: The results indicate that the developed mathematics learning tools are valid, practical, and effective. Therefore, they can be used in the classroom without requiring significant changes.

INTRODUCTION

Problem-solving skills are a fundamental aspect of learning mathematics, fostering logical, analytical, and creative thinking in students. Research consistently highlights the importance of these skills in mathematics education, as they are linked to essential cognitive abilities required for academic success and real-world applications. For example, Lovianova et al. (2022) found that a problem-based approach significantly enhances high school students' logical reasoning, underscoring the role of problem-solving in developing critical thinking skills. Similarly, Hidayat & Evendi (2022) showed that engaging in mathematical problem-solving enhances students' creativity, reinforcing the connection between problem-solving and creative thinking, a relationship also noted by Aizikovitsh-Udi (2014) among mathematically talented students. Furthermore, Purwasih et al. (2019) argue that creative thinking in mathematics combines logical and divergent thinking, which are essential components of effective problem-solving. This view is supported by , who emphasize creative thinking as a crucial cognitive process for navigating mathematical challenges. Integrating problem-solving tasks within a guided discovery framework not only strengthens students' cognitive skills but also equips them

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with practical tools to approach complex mathematical challenges with confidence and independence.

Guided discovery learning plays a crucial role in mathematics education by encouraging structured exploration of concepts, which fosters active engagement and deeper understanding. This method has shown success in enhancing students' comprehension and retention, as it encourages them to construct knowledge through inquiry and problem-solving. Yusuf et al. (2023) found that students using guided discovery learning achieved significantly higher problem-solving skills than those in traditional instruction, due to the inductive, exploration-based structure of this approach. Furthermore, instructional materials designed with guided discovery increase student engagement and comprehension, supported by the importance of scaffolding to aid students in mastering complex ideas (Alfieri et al., 2011; Suharti et al., 2020). Kpotosu (2023) also noted its effectiveness, demonstrating that concrete manipulatives within a guided discovery framework improve math achievement, and Supriadi et al. (2019) observed enhanced conceptual understanding and problem-solving skills over conventional methods. Moreover, guided discovery promotes creative thinking, with exploratory tasks fostering effective creative problem-solving (Soewardini et al., 2022; Yuliana et al., 2017). With these benefits, guided discovery learning holds strong potential for integration into mathematics instructional media, allowing students to actively engage, deepen understanding, and build critical thinking skills.

Despite its advantages, guided discovery learning often lacks instructional media specifically designed to fully support its approach. Without suitable media, guided discovery's full potential may be limited (Said et al., 2019). Integrating media like Discord with guided inquiry enhances learning outcomes by structuring exploration (Akmar et al., 2024). Tailored media, such as critical thinking tools and fractional wheels, strengthen students' critical thinking abilities in guided discovery frameworks (Lestari et al., 2021; Susanti & Purbandari, 2024). Additionally, guided discovery strategies paired with instructional media have been shown to improve student retention and attitudes toward learning, highlighting the added value of media-enhanced guided discovery (Ugwoke et al., 2020). Collectively, these studies indicate that while guided discovery is inherently valuable, instructional media designed to maximize its benefits are essential for supporting mathematics education effectively.

Incorporating instructional media specifically designed for guided discovery learning not only enhances student engagement and understanding but also addresses the need for validated, accessible resources to maximize this approach's benefits. Guided discovery learning relies on structured instructional media to optimize student engagement, understanding, and critical thinking in mathematics education. Previous studies on discovery learning-based media in mathematics have mainly focused on improving conceptual understanding (Mukhtar et al., 2023), problem-solving skills (Darmawan & Suparman, 2019), digital literacy (Situmorang, 2023), learning outcomes (Fikriah et al., 2021; Nikmah & Qohar, 2023; Rahmawati et al., 2022), and mathematical analysis (Tusa'diah & Asmar, 2021). Although Darmawan & Suparman (2019) developed digital media using discovery learning, their research did not fully address the

validity of graphics, language, and content. To fill this gap, our study develops non-digital Learning Activity Sheets (LKPD) based on discovery learning, with a focus on clear visuals, precise language, and accurate content. Unlike digital media, LKPD serves as a physical, accessible resource, especially valuable in schools with limited technology. By enhancing the validation process, this study aims to create effective learning materials that better support mathematics education. The goal of this study is to design mathematics learning tools based on Guided Discovery Learning that are valid, practical, and effective in improving high school students' problem-solving abilities.

METHODS

Research Design:

This study employs a development research design, which systematically addresses the creation, testing, and improvement of educational tools to resolve complex challenges within educational settings. Development research focuses on generating practical solutions that are validated and refined through systematic evaluations. Specifically, this study uses the development model proposed by Tjeerd Plomp, which is structured into three main phases. The first phase, the initial investigation phase, involves analyzing the needs of learners, the curriculum, and the relevant concepts to establish a foundation for designing suitable learning tools. In the development or prototyping phase, the research iteratively designs and improves learning tools such as lesson plans (RPP) and student worksheets (LKPD) through formative evaluation, adjusting the prototype at each stage based on feedback and testing. Finally, in the assessment phase, a semi-summative evaluation assesses the effectiveness of the developed learning tools and provides recommendations for further refinement. This structured approach ensures that the resulting tools are both practical and capable of enhancing learning outcomes.

Participants:

The participants in this study include three main groups: expert validators, teachers, and students. Expert validators consist of professionals in the field of education who review the developed learning tools for accuracy, relevance, and appropriateness. Their feedback is critical for assessing the validity of the instructional design, content, and usability of the materials. Teachers participating in the limited trials provide practical insights and feedback on the feasibility of the learning tools in a real classroom setting, contributing to assessments of the materials' practicality. Students, as the primary users, engage with the learning tools during limited trials, where their responses and performance data help evaluate the effectiveness of the tools in improving problem-solving skills and enhancing engagement with the material.

Instruments:

This research uses multiple instruments to collect comprehensive data on the development and implementation of the learning tools. Questionnaires are distributed to expert validators to assess the validity of the materials and to teachers and students to gather feedback on the practicality and usability of the tools. Interview guides are prepared to gain qualitative insights from validators, teachers, and students, allowing

researchers to explore participant perspectives in more depth. Additionally, tests are designed to measure students' problem-solving abilities before and after using the learning tools, providing quantitative data on the effectiveness of the intervention. These instruments together ensure a well-rounded evaluation of the learning tools from both qualitative and quantitative perspectives.

Data Analysis:

Data analysis in this research consists of three main components: validity, practicality, and effectiveness. Validity analysis uses questionnaire data from expert validators to evaluate the accuracy and suitability of the developed lesson plans (RPP) and student worksheets (LKPD) for the intended educational context. Practicality analysis is conducted using feedback from teachers and students, examining how effectively the tools can be implemented in a classroom setting and how they meet users' needs. Lastly, effectiveness analysis is performed through pre-test and post-test comparisons, assessing the improvement in students' problem-solving skills after engaging with the learning tools. By triangulating data from validators, teachers, and students, the study offers a comprehensive evaluation of the developed materials, ensuring they meet high standards for educational practice.

RESULTS AND DISCUSSION

This research aims to develop teaching modules and instructional materials in the form of LKPD based on Guided Discovery Learning that are valid, practical, and effective in improving the mathematical problem-solving abilities of Class X high school students. The research findings are presented according to the stages of development in the Plomp model, namely the preliminary research phase, the development or prototyping phase, and the assessment phase.

Result

In the Preliminary Research phase, the needs analysis identified that both teachers and students required additional learning tools to make mathematics learning more active, enjoyable, and capable of enhancing student competencies. Observations and interviews conducted with 48 students at SMA N 1 Sipora revealed that while students generally found mathematics to be enjoyable, their learning resources were limited to textbooks. Additionally, the curriculum analysis showed that the school uses the independent curriculum for Class X, while Classes XI and XII follow the 2013 curriculum.

1. Validity Result

In the Development or Prototyping phase, the validation process was carried out through a series of trials and revisions. Based on the results, the developed product was declared valid and suitable for use as supplementary teaching material in mathematics classes at SMA N 1 Sipora. This validation process ensures that the modules and LKPD align with the curriculum and are appropriate for enhancing the problem-solving skills of high school students.

Table 1. Graphics Expert Assessment

No	Indicator	Aiken's V	Kriteria
1	Proportional letter shape and size	0,667	Valid
2	The layout of the contents of the teaching module is attractive	0,667	Valid
3	The images presented in the teaching module are clear	0,667	Valid
4	The use of color in the teaching module is interesting	1	Valid
	Average	0,75	Valid

Based on table 1 above, it can be seen that the average score obtained from the graphic validator is 0.75, meaning that the module is valid in the high category based on graphic aspects. The following are the results of the validity analysis of the language module.

Table 2. Validity of Module Language

No	Rated aspect	Aikens V	Ket
1	The type of writing is easy to read	1	Valid
2	The language used is simple	1	Valid
3	and effective	1	Valid
4	Punctuation appropriateness	0,67	Valid
5	The sentences used are easy	1	Valid
6	Understood	1	Valid
	Average	0,944	Valid

Based on Table 2 above, it can be seen that the language validity value obtained is 0.944 with a very high valid category. Language validity helps ensure that the information presented in the module can be clearly understood by students. Then, in the context of content validity, it is important to ensure that the module accurately represents the concepts, information or skills to be taught. The validator for the content and presentation of the Module is Mr. Dr. H. Yaman, M.Pd, Dr Arnelis M.Pd and Prof. Dr. Yerizon, M.Si. The following are the results of the content validity test of the Guided Discovery Learning-based teaching module:

Table 3. Module Content Validity Test Results

Rated Aspect	Aikens'V	Category
Suitability of Module Content	0,837	Very high

Based on Table 3 above, it can be seen that the modules prepared are in good condition. The average Aikens'V value obtained was 0.837 in the valid category (very high). This means that the modules prepared are in accordance with the learning objectives. Next, a validity test of the module presentation was carried out with the following results: validity assessment:

Table 4. LKPD Content Validity Test Results

Rated aspect	Aiken's V	Categories
Didactic Presentation	0,847	Very Higth

Based on Table 4 above, it can be seen that the LKPD has been prepared well as evidenced by the results of the content validity assessment, namely 0.847 in the very high Valid category. Furthermore, active validation (presentation) was also carried out with the following results:

Table 5 Active Validity Test Results (Presentation) of LKPD

Rated aspect	Aiken's V	Category
Presentation (Didactive)	0,88	Very High

Based on Table 5 above, the Aikens V value is 0.88. This value is in the very high valid category. A good LKPD is guaranteed to be neatly arranged and easy to read. Next, graphical validity is carried out. The LKPD graphic validator is Dr Darmansyah S.T M.Pd. The following are the results of the validity of graphics (display) based on Guided Discovery Learning:

Table 6 Result of LKPD Graphic Validity Test (Display) Based on Guided Discovery Learning

Rated aspect	Aiken's V	Categories
Graphics (View)	0,74	Highgt

Based on Table 6 above, a validity value of 0.74 is obtained, meaning it is valid in the high category. The graphic validity of LKPD is important to increase students' attractiveness and understanding of learning material. By paying attention to the aspects above, graphic elements can be an effective tool in supporting the learning process. Language Validation was carried out by Dr Abdurahman M.Pd. The following are the results of the LKPD language validity test based on Guide Discovery Learning.

Table 7 Language Validity Test Results for LKPD Based on Guided Discovery Learning

No	Rated aspect	Value of the Validator	Aikens'V	Categories
1	This type of writing is easy to understand and interesting.	4	1	Very high
2	The language used is appropriate to the level of understanding of students in class X SMA or phase E.	4	1	Very high
3	The sentences used are easy to understand.	4	1	Very high
4	The sentences used are in accordance with the General Guidelines for good and correct Indonesian Spelling (PUEBI).	4	1	Very high
5	The way of writing terms, symbols and mathematical equations is appropriate.	3	0,667	Tall
	Average		0,933	Very High

Based on Table 7, the results of the LKPD language validity test based on guided discovery learning obtained a value of 0.933 with a very high valid category. This means that in terms of language, this LKPD can be used without correction. Efforts to achieve high language validity encourage the development of better and more effective language measurement instruments. If task instructions are not clear on the LKPD students may have difficulty understanding what they are supposed to do.

2. Practicality Result

After the validity test is carried out, the practicality test is then carried out. The practicality of the modules and LKPD is related to the ease of use of the modules and LKPD being developed. The practicality results were obtained from practitioners' responses, namely the class X mathematics teacher at SMA N 1 Sipora. Based on filling out the questionnaire, you can see the results of the practicality of the LKPD according to teacher and student responses in Table 8

Table 8 Results of Implementation Test of Guide Discovery Learning Based Teaching Modules

No	Assessment aspect	Persentase	Category
1.	Preliminary activities	96,76%	Very Practical
2.	Core activities	92,70%	Very Practical
3.	Closing Activities	95,6%	Very Practical
	Average	95,15%	Very Practical

Based on Table 8 above, there are results for the implementation of teaching modules at SMA N 1 Sipora with a percentage score of 95.15 in the very practical category. Next, the results of the practicality test of students' responses to the teaching modules developed are presented.

Table 9 Practicality Test Results for Guide Discovery Learning Based Teaching Modules Educator Responses

No	Assessment aspect	Persentase	Kategori
1.	Readability and clarity of material	100%	Very Practical
2.	Applicability and clarity of use	100%	Very Practical
3.	Attractiveness	100%	Very Practical
4.	Suitability of time allocation	75%	Very Practical
	Average	93,75%	Very Practical

Based on table 9 above, it can be seen that the ease of use of the module by students is very easy. This is proven by the student assessment of 93.75% in the very practical category. A very practical module means the ability or characteristics of a module (component or part of a system) to be used or applied in an efficient, simple and effective way. Apart from the modules that are given a practicality test, the LKPD is also given the same treatment to test its ease of use. The following are the results of the LKPD practicality test:

Table 10 Practicality Test of LKPD Based on Guided Discovery Learning Student Responses

No	Assessment aspect	Persentase	Category
1.	Readability and clarity of material	85,73%	Very Practical
2.	Applicability and clarity of use	85,24%	Very Practical
3.	Attraction	95,6%	Very Practical
4.	Suitability of time allocation	81,25%	Very Practical
	Average	85,45%	Very Practical

Based on table 10 above, it can be seen that the practicality test results obtained a score of 85.45%. This shows that the prepared LKPD provides ease of use. Below are presented the results of the practicality test of teacher responses as follows:

Table 11. LKPD Practicality Test Based on Guided Discovery Learning Student Responses

No	Assessment aspect	Persentase	Category
1.	Readability and clarity of material	100%	Very Practical
2.	Applicability and clarity of use	93,75%	Very Practical
3.	Attractiveness	100%	Very Practical
4.	Suitability of time allocation	75%	Very Practical
	Average	92,19%	Very Practical

Based on Table 11 above, it was found that the results of the practicality test of LKPD based on Guide Discovery Learn and Student Response were 92.19% in the very practical category. LKPD creates a positive and efficient learning experience, this can create better conditions for objective assessment and evaluation of students' understanding. The practicality test results for the development of guided discovery learning-based mathematics learning tools are in line with research conducted by Suryawan (2014) with the same development object, namely the Development of Mathematics Learning Tools for Open Problem-Oriented Reasoning and Problem Solving Learning Models (MP3m) with very practical results.

3. Effectiveness Results

The next step after the learning tools are valid and practical is to continue with effectiveness testing. The effectiveness test is a test carried out to measure the level of success in using LKPD in improving student learning outcomes. Differences in learning outcomes can be seen from the completeness of students' learning outcomes. The completeness of learning outcomes was obtained from the pre-test (initial test) and post-test (final test) assessments which were attended by 24 students from class X who had carried out learning using LKPD which had been tried out. The results obtained through analysis using the Ms. application program. The Excel of 24 students' pre-test average was 20.375 while the post-test average was 85.2. From the results of the pre-test and post-test assessments, a gain score of 0.814 was obtained in the high category. The results of this research are in line with research conducted by Kurniati (2013) entitled Development of Mathematics Learning Tools for Open Problem-Oriented Reasoning and Problem Solving Learning Models (Mp3m). The results of the research are that the product developed also meets th effectiveness criteria because 90% of students have completed the learning outcomes and 80% of students have good character. Interesting and relevant LKPD can increase student involvement in the learning process. Well-designed activities can motivate students to actively participate in learning. Effective LKPD can help in the development of various skills, such as research, analytical, critical and problem solving skills. This gives students the opportunity to develop competencies needed in the real world.

Discussion

The results of this study indicate that the teaching modules and student worksheets (LKPD) based on Guided Discovery Learning developed in this research demonstrate high validity, practicality, and effectiveness in enhancing the problem-solving skills of 10th-grade high school students in mathematics. The high validity signifies that these learning materials align well with students' needs, comprehension levels, and the curriculum used in schools. The practicality, rated as "very practical" by both teachers and students, indicates that the LKPD is easy to use and engaging, which can encourage greater student participation in learning. The effectiveness, evidenced by significant improvement in post-test scores compared to pre-test scores, supports the hypothesis that well-designed Guided Discovery Learning materials can improve problem-solving skills. These findings are relevant in addressing the initial research problem, namely, the lack of interactive and effective learning materials for teaching mathematics in high school.

These results have significant implications for the target population, namely students and teachers. For students, the success of these modules and the LKPD in enhancing problem-solving skills shows that Guided Discovery Learning materials help them develop critical, analytical, and creative thinking skills—key competencies in mathematics education. For teachers, this study offers an alternative learning material that is both practical and easy to use, which can diversify their teaching methods and make the learning process more engaging and effective. Given these results, schools might consider adopting Guided Discovery Learning materials more broadly within the mathematics curriculum to improve student engagement and understanding.

This study also makes an important contribution to the existing literature on the effectiveness of Guided Discovery Learning in mathematics education. Previous studies, such as those by Mukhtar et al. (2023), have shown that discovery-based approaches, particularly in structured environments, can strengthen students' conceptual understanding and help them build critical and analytical thinking skills. Additionally, research by Alfieri et al. (2011) has revealed that Guided Discovery Learning is more effective than direct instruction in enhancing problem-solving skills, especially when accompanied by adequate scaffolding. Other studies by Suharti et al. (2020) and Yusuf et al. (2023) found that discovery-based learning materials boost student engagement in the learning process, which contributes to better learning outcomes. However, this study provides additional empirical evidence by highlighting the effectiveness of non-digital instructional media specifically designed for high school curricula in Indonesia—an approach that has not been widely explored. With high validity, practicality, and effectiveness, this study supports the literature that Guided Discovery materials can create a more meaningful and contextual learning experience for students (Alfieri et al., 2011; Suharti et al., 2020; Yusuf et al., 2023). Positioned within the existing literature, this study not only reinforces previous findings but also expands our understanding by showing that non-digital learning media can be an effective alternative for educational environments with limited access to technology.

Nevertheless, there are some limitations in this study that suggest areas for further research. This study was conducted on a limited scale, involving only one school with 48 students in a single class, so caution should be taken when generalizing the results to a broader population. Additionally, since this research used a non-digital approach, the effectiveness of Guided Discovery Learning LKPD in classrooms with more integrated technology remains untested. The long-term impact of these materials has also not been evaluated; it is unknown whether the positive effects on students' problem-solving skills will persist over time or are only temporary. Therefore, further studies with larger and more diverse samples are needed to strengthen the generalizability of the findings.

Future research is also encouraged to explore the integration of technology in Guided Discovery Learning to see how digital media or learning applications could further enhance learning outcomes. Longitudinal studies would be particularly valuable in assessing the long-term effects of these materials on students' problem-solving skills. Additionally, in-depth research focusing on specific aspects of Guided Discovery Learning, such as its impact on students with different learning styles or its effect on higher-order thinking skills, could provide valuable insights for developing more effective teaching methods in the future.

CONCLUSIONS

This study successfully developed Guided Discovery Learning-based teaching modules and student worksheets (LKPD) that are valid, practical, and effective in enhancing the problem-solving skills of 10th-grade high school students in mathematics. The high validity confirms the alignment of these materials with student needs, comprehension levels, and curriculum requirements, while their practicality, rated as “very practical” by teachers and students, indicates ease of use and engagement in learning activities. The significant improvement in students’ post-test scores highlights the effectiveness of these materials in fostering critical thinking and analytical skills. This study adds to the existing literature by demonstrating the potential of non-digital Guided Discovery Learning resources as a viable alternative in educational settings with limited technology access, as is common in many Indonesian schools. Despite the study’s limited scope, it offers a solid foundation for future research to explore broader applications, such as digital integration and long-term impacts. These findings support the implementation of Guided Discovery Learning within the mathematics curriculum to create a more interactive and meaningful learning experience for students.

AUTHOR CONTRIBUTION STATEMENTS

Wina Friliza Putri led the conceptualization and design of the study, conducted data collection, and performed the initial data analysis. She was also responsible for drafting the manuscript.

Edwin Musdi provided critical input on the research methodology, assisted in refining the data analysis, and reviewed the manuscript for intellectual content. Both authors discussed the results, contributed to the final revisions of the manuscript, and approved the final version for submission.

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