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Development of LKPD Based on Higher Order Thinking Skills to Improve Mathematical Problem-Solving Skills

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ABSTRACT

Higher level thinking skills (HOTS) and mathematical problem-solving skills are still the main problems in mathematics learning at the high school level, especially on the topic of rows and series. Field observations show that many students experience obstacles in finding patterns, relating concepts, and using formulas to solve contextual problems. This situation indicates the need for more innovative teaching tools, not limited to procedural exercises, but also to cultivate critical, analytical, and creative skills. This research is designed to produce a valid, practical, and effective HOTS-based Student Worksheet (LKPD) in improving mathematical problem-solving skills. The method used is Research and Development (R&D) with the ADDIE model, involving 70 class X students at SMA Negeri 1 Sihapas Barumun. The research instruments consist of expert validation sheets, teacher and student questionnaires, pretest–posttest tests, and observation of learning implementation. The results of the study showed that LKPD met valid criteria, received a practical response, and was proven to be effective in improving problem-solving ability with medium to high N-gain categories. Thus, HOTS-based LKPD is worthy of being used as an innovative tool in line and series materials to support 21st century skills.

INTRODUCTION

The rapid development of information technology, the demands of globalization, and the increasing complexity of problems in the 21st century confirm that *Higher Order Thinking Skills* (HOTS)—which includes the ability to analyze, evaluate, and be creative—are key competencies that must be possessed by students (Hidayah, 2023); Kusumaningtyas, 2024). HOTS not only serves to expand the mastery of academic knowledge, but also plays an important role in forming adaptive critical thinking and problem-solving skills, so that students are able to deal with various new situations more effectively (Omanda et al., 2023). In addition, the 21st century competency framework places critical thinking, problem-solving, and creativity skills as key pillars to prepare students for real-life challenges. In line with that, the development of HOTS-based teaching tools, such as contextual LKPD, has been proven to encourage the improvement of high-level thinking skills while strengthening learning independence (Niwanggalih, 2023); (Karwadi, 2024). Thus, HOTS has become an important foundation in contemporary education that aims not only to produce academically intelligent graduates, but also to be resilient in adapting to global dynamics.

The results of international assessments such as PISA and TIMSS show that many education systems in the world still face major challenges in fostering *Higher Order Thinking Skills* (HOTS). The data showed a significant gap in students' mathematical abilities, especially because the questions used still tended to be oriented to memorization and procedure alone (Kadijevich, n.d.). This condition raises concerns that students are undertrained in developing critical, analytical, and creative thinking skills, which are actually the main pillars of 21st century competence. In addition, the TIMSS report highlights the weak application and reasoning skills of students when faced with contextual or open-ended problems, thus showing that mathematics learning is not fully able to equip students with complex problem-solving skills (OECD, 2023). This fact emphasizes the urgency of reform of mathematics education, both in curriculum, learning instruments, and assessments. The reform must be directed at the creation of a learning experience that emphasizes the development of HOTS, so that students are able to adapt to global dynamics that demand creativity, innovation, and high-level thinking skills.

Thus, the strengthening of HOTS becomes a very important foundation in modern mathematics education. The development of HOTS-based Student Worksheets (LKPDs)—especially on row and series materials—can be seen as a strategic step to encourage students not only to understand concepts procedurally, but also to practice critical, analytical, and creative thinking skills. HOTS-based LKPD serves as a bridge between theory and practice, as well as answering the gap between learning to memorize and the demands of high-level thinking skills required in PISA, TIMSS, and the challenges of the 21st century (Hidayah, 2023).

In fact, mathematics learning at the high school level is still often dominated by mechanistic routine problems. Most exercises focus only on applying formulas without understanding the concepts behind them. This approach leads to rote learning—an instant but tangible result in understanding—which inhibits the transfer of knowledge to new situations as well as the inability to deal with non-routine problems that require complex reasoning (Kusumaningtyas, 2024). The phenomenon of rote learning has long been a concern. In the modern context, these limitations are exacerbated by the global demands for adaptability and criticality. Therefore, the development of HOTS-based LKPD is a relevant solution—designed with contextual, open, and challenging questions so that students are trained to understand problems, plan strategies, implement solutions, and evaluate their learning outcomes (Omanda et al., 2023).

As a result of this practice, students are not flexible in thinking. When faced with non-routine problems, they tend to rely on standard procedures even if they are not in context—indicating the limitations of problem-solving. A HOTS-based approach is important to foster creativity, reflectivity, and high-level thinking as a provision in the era of globalization (Niwanggalih, 2023). In addition, row and series material has a strategic role because it is able to train the systematization of applied thinking; Connecting number patterns with advanced concepts such as infinite series, limits, and mathematical modeling. This approach encourages students to think logically and structurally in understanding abstract concepts contextually (Kusumaningtyas, 2024).

Furthermore, the application of rows and sequences in everyday life makes them highly relevant to the needs of the modern century. For example, this concept can be used to understand compound interest calculations, population growth predictions, and analysis in the fields of science, economics, finance, and engineering (Jones, 2021). By understanding the patterns and structures of numbers, students are not only limited to mastering formulas, but also able to develop analytical accuracy and numerical skills. This shows that linear and sequential learning can be a strategic means to cultivate high-level thinking skills that are essential for academic and professional success. Although rows and sequences are fundamental mathematical concepts as well as rich in applications, this material is often a source of difficulty for students. A number of studies show that many students are still weak in following the steps of solving problems, especially in recognizing patterns, abstracting problems, and choosing the right solution strategies (Saifurrisal, 2022). Mistakes that often arise include misinterpreting the context of the question, being unable to relate information to previous concepts, and difficulty evaluating results according to the Polya stage. The findings underscore the importance of developing innovative teaching tools, such as the HOTS-based Student Worksheet (LKPD), to encourage in-depth understanding while improving problem-solving skills.

The results of previous research also show that the LKPD developed still tends to be procedural and has not fully integrated a contextual approach to foster Higher Order Thinking Skills (HOTS). For example, the study of Rahmadhani, Mulyono, and Hapizah (2025) found that although the LKPD on row and sequence material was declared valid and practical, the main focus was more on strengthening *computational thinking* without putting pressure on real-life contexts or non-routine problems that challenged HOTS. Similarly, Tumangger (2024) research using the Realistic Mathematics Education (RME) approach has been shown to improve problem-solving skills, but the association of the material with the everyday context is still limited to certain parts. This condition shows the need for the insertion of a wider context in order for the potential of HOTS to be optimized.

Although some HOTS-based LKPD developments have been carried out at the junior high school level (e.g., HOTS-oriented LKPD by SMP Negeri 7 Yogyakarta which shows high validity and effectiveness; Izzati, 2024), is still limited in its applicative context—the main focus is on improving non-routine problem-solving skills, without deep contextual linkages. Thus, there is a significant research gap, namely the need for the development of HOTS-based LKPD that is not only valid, practical, and effective, but also contextually developed—that is, designed by including real problems or situations relevant to students' lives, to strengthen the application of HOTS in row and series learning.

The purpose of this research is to develop a HOTS-based LKPD that meets valid, practical, and effective criteria to improve students' mathematical problem-solving skills in row and series materials. The development model used follows R&D frameworks such as ADDIE, which has been proven to be successful in producing feasible and applicable LKPD in various mathematics lesson contexts (Sutarni et al., 2024). By designing LKPD that is valid according to experts, practical according to direct users (teachers and students), and effective based on the results of improving students' abilities (e.g. through N-gain analysis and pretest–posttest differential tests), it is hoped that this teaching tool will be an innovative solution to strengthen 21st century competencies in the local context of schools.

METHODE

This research is included in the category of research and development (R&D) by applying the ADDIE model, which consists of five main stages, namely Analysis, Design, Development, Implementation, and Evaluation (Adeoye et al., 2024). The selection of the model is based on its ability to provide consistent and systematic work steps in producing learning tools that are not only valid, but also practical and effective. The research was carried out at SMA Negeri 1 Sihapas using the One-Group Pretest–Posttest design. This design is considered appropriate because it provides an opportunity to compare the learning outcomes of students before and after the use of the designed device (Hasibuan, 2022;

Wahyudin, 2024). A total of 70 students of class X were involved as research subjects, so that they could represent real conditions in the field as well as test the quality of the product in actual learning situations.

The research instruments used are comprehensively designed to be able to assess the feasibility, practicality, and effectiveness aspects of the product. The instruments include expert validation sheets that evaluate the content, language, construction, and integration of Higher Order Thinking Skills (HOTS) aspects; questionnaires of teacher and student responses that assess the level of product practicality; as well as a mathematical problem-solving ability test based on Polya steps. In addition, the learning implementation observation sheet is also used to provide a more detailed overview of the process of implementing products in the classroom. Research data was collected through needs questionnaires, expert validation, pretest and posttest tests, classroom observations, and documentation. Data analysis is carried out by integrating quantitative and qualitative approaches. Product validity is calculated based on the average validator score; practicality is analyzed through the percentage of teacher and student responses; The effectiveness of the product was measured using the N-gain test and the achievement of minimum learning completeness (KKM). Meanwhile, the observation data was analyzed in a qualitative descriptive manner to describe the implementation of learning—thus producing complete findings regarding the quality of development products.

RESULT AND DISCUSSION

Based on the results of validation involving mathematics education lecturers, media experts, and practitioner teachers, the HOTS-based LKPD developed obtained a high average score in all aspects of the assessment. In the content aspect, for example, this teaching tool achieved an average score of 3.6 out of a scale of 4 with a very valid category. The findings indicate that the row and series material presented have been aligned with the curriculum and integrate problem-solving indicators according to the Polya stage. Therefore, the content of the LKPD is considered relevant and able to support the achievement of the set learning objectives. In terms of language, LKPD obtained an average score of 3.5 with a valid category. This assessment is based on the clarity of the sentences used, which are considered communicative and easy to understand by students. The ease of language in the LKPD is one of the important factors so that students can follow the instructions well and be able to relate the material to the learning activities provided. In addition, the presentation aspect received an average score of 3.7 with a very valid category. This is because the preparation of the LKPD is considered systematic, logical, and able to display interesting learning activities so as to motivate students to be actively involved.

Furthermore, the integration aspect of HOTS obtained an average score of 3.6 with a very valid category. This reflects that the activities contained in the LKPD have been consistently designed to train high-level thinking skills, including the ability to analyze, evaluate, and create. This validation is in line with the results of Septiani, Yuhana, and Sukirwan (2022) research, which affirms that learning tools can be said to be valid if the HOTS indicator is fully integrated into the content and learning activities. In other words, the LKPD developed is not only materially relevant, but also effective in directing students towards higher-level thinking skills.

Table 1. Results of HOTS-Based LKPD Expert Validation

Aspects Assessed	Average Score	Category
Isi	3,6	Highly Valid
Language	3,5	Valid
Presentation	3,7	Highly Valid
HOTS Integration	3,6	Highly Valid
Total Average	3,6	Highly Valid

The practicality of HOTS-based LKPD was evaluated through a response questionnaire given to teachers and students with the scope of assessment on the aspects of readability, ease of use, clarity of instruction, and benefits obtained in learning. The results of the questionnaire showed that the average response of teachers reached 87% and student responses of 84%. This percentage is categorized as very practical because it exceeds the minimum limit of 70% set as the eligibility standard. These findings show that the LKPD developed is able to be applied effectively in the context of real learning.

From a teacher's point of view, LKPD is considered very helpful in managing problem-solving-based learning. Teachers feel that the activity structure in the LKPD makes it easier for them to develop systematic learning steps and present problems that are relevant to the competencies they want to achieve. Meanwhile, students assessed that LKPD not only made the material of rows and sequences easier to understand, but also presented challenges that encouraged them to think more critically and contextually. This shows that HOTS-based LKPD has a dual role: as a pedagogical instrument for teachers as well as a learning medium that empowers students.

These results are in line with the research of Wulandari, Mulyatna, and Surya (2022) who emphasized that HOTS-based LKPD is practically used in geometry learning. The study found that the existence of HOTS-based LKPD was able to increase student active participation while making it easier for teachers to present non-routine questions. Thus, it can be concluded that the practicality of HOTS-based LKPD can be seen not only from the high percentage of positive responses, but also from the real impact in supporting more interactive, contextual, and development-oriented learning of higher-level thinking skills.

Table 2. Results of HOTS-Based LKPD Practicality Test

They respond	Percentage (%)	Category
Teacher	87	Very Practical
Students	84	Very Practical
Average	85,5	Very Practical

The effectiveness of HOTS-based LKPD was evaluated through a comparative analysis of pretest and posttest scores on students' problem-solving abilities. The results showed that the average score of the students' pretest was 55.4 increased to 78.6 in the posttest. In addition, the classical completeness percentage reached 82%, which means that it has exceeded the Minimum Completeness Criteria (KKM) set. This data provides an idea that the implementation of LKPD is able to have a positive impact on improving students' mastery of concepts and mathematical problem-solving skills.

Furthermore, the effectiveness of LKPD was also strengthened by the results of the calculation of N-gain of 0.56 which was included in the medium category. This figure shows a significant increase in students' conceptual understanding after participating in learning using HOTS-based LKPD. This increase indicates that LKPD not only provides new knowledge, but also equips students with better thinking strategies in solving mathematical problems. Thus, LKPD plays a role as a medium that is able to bridge the gap between procedural mastery of material and high-level thinking skills.

These findings are in line with the research of Maimunah, Hariani, and Yuanita (2023) which states that HOTS-based teaching tools have proven to be effective in improving the mathematical problem-solving skills of high school students, with the category of increasing N-gain in the medium to high range. This confirms that the HOTS-based LKPD developed not only meets the aspects of validity and practicality, but is also effective as an innovative learning tool for row and series materials. With this effectiveness, LKPD has the potential to continue to be developed and applied in mathematics learning at various levels of education to strengthen students' high-level thinking skills.

Table 3. Results of HOTS-Based LKPD Effectiveness Test

Parameter	Pretest	Posttest	N-Gain	Category	Remarks
Average Score	55,4	78,6	0,56	Medium	Effective increase ability
Completion Percentage (%)	38%	82%	–	–	Exceeding MOH (≥75% of students complete)

The results of the experts' validation show that the HOTS-based LKPD developed is included in the category of very valid in terms of content, language, presentation, and integration of HOTS indicators. The positive assessment confirms that the material contained is in accordance with the demands of the curriculum, presented in clear and easy-to-understand language, and designed in a format that supports learning objectives. This validation provides assurance that the LKPD is not only theoretically feasible, but also ready to be applied in learning practice to support the development of students' high-level thinking skills. This is in line with the findings of Afriliyanti et al. (2023) who showed that HOTS-based interactive LKPD on ecosystem materials obtained a media validity of 82% (very feasible) and a material validity of 72.7% (feasible).

The suitability of the content aspect with the curriculum is the main factor in ensuring the integration between teaching tools and the academic needs of students. The row and series materials presented in the LKPD have been arranged based on learning indicators that refer to basic competencies, so they are relevant to help students understand concepts more deeply. In addition, the use of communicative language makes LKPD easier to understand and accessible to various levels of students' abilities. This view is supported by Kahar et al. (2021) who stated that validation tests by experts on the format, substance, grammar, and benefits of worksheets showed "good" to "very valid" validity results before field tests were continued.

In terms of presentation, LKPD is designed systematically by displaying challenging and interesting activities, so as to increase students' motivation to learn. A good presentation includes a logical flow of activities, a supportive visual display, and clear instructions. With presentations like this, students can more easily follow the learning flow, understand the steps to solve problems, and relate concepts to real context. Quality presentation is also one of the benchmarks for construct validity—where the format and structure of the LKPD must be able to reflect the integration between theory and implementation. Noprinda and Soleh (2019) also emphasized that HOTS-based LKPD is suitable for use in the context of education and supports the achievement of student learning outcomes.

This validity finding corroborates the view of Akker (2013) that teaching tools that are declared valid must meet at least three criteria, namely content validity, construct validity, and display validity. These three aspects complement each other in ensuring the acceptance of teaching tools as an effective learning medium. With the fulfillment of these three aspects in the HOTS-based LKPD, it can be concluded that this tool not only meets academic development standards, but is also relevant to the real needs of students to develop high-level thinking skills. High validity is an important foundation for the effectiveness of the implementation of LKPD in improving the quality of mathematics learning in schools. The results of the practicality test obtained from the responses of teachers and students showed that HOTS-based LKPD was included in the category of very practical. This indicates that the teaching tool is easy to use and can be effectively integrated into daily learning activities. This high level of practicality reflects that the LKPD is not only theoretically appropriate, but also able to be applied well in the context of real learning in the classroom. Thus, LKPD can be seen as a learning instrument that is able to answer the practical needs of teachers and students while supporting the achievement of curriculum goals. This practicality is in line with the theory of Plomp and Nieveen (2013) who affirm that an educational product must meet three main criteria, namely that it can be applied efficiently in real situations, is well received by users, and provides direct benefits to learning. HOTS-based LKPD has proven to be able to meet these three criteria. Efficiency can be seen from the teacher's ease in managing the learning process, acceptance is shown through the positive response of teachers and students, while the direct benefits are reflected in increased student involvement in learning row and series material.

Teachers feel that the existence of LKPD is very helpful in arranging learning that is oriented towards problem solving. The systematic structure of the LKPD makes it easier for teachers to direct students to think critically and follow more targeted problem-solving steps. Meanwhile, students consider LKPD as a medium that is able to make row and series material more meaningful. Through activities that are designed to be contextual and challenging, students feel more challenged to think deeply, explore new strategies, and connect mathematical concepts to real-life situations.

In addition, the practicality of this LKPD also strengthens the practicality criteria stated by Riduwan (2012), namely that a teaching tool can be declared practical if at least 70% of user responses state that it can be used properly. The results of the study show that the response of teachers and students exceeds this limit, even in the category of very practical. This confirms that HOTS-based LKPD is not only valid in terms of content, but also practical to be applied in mathematics learning. As such, these tools have great potential to be widely applied in an effort to improve the quality of learning that emphasizes the development of high-level thinking skills. The HOTS-based LKPD developed in this study not only meets the aspects of validity and practicality, but also proves to be effective in improving students' mathematical problem-solving skills. This can be seen from the results of the pretest and posttest analysis which showed a significant increase after learning using LKPD. The increase was measured through the N-gain value which was in the medium category, as well as accompanied by a classical completeness percentage of more than 75%. These findings indicate that LKPD is able to have a real impact on improving the quality of student learning.

This effectiveness supports the theory of Hake (1999), who emphasizes that the success of a teaching tool can be judged by the magnitude of a statistically significant increase in N-gain scores. With the N-gain value obtained, HOTS-based LKPD can be categorized as effective because it is able to encourage students to progress in understanding concepts while applying them in problem solving. This shows that learning instruments designed with the HOTS principle can function optimally in forming more complex mathematical thinking skills. Furthermore, the effectiveness of LKPD is also in accordance with Polya's (1973) view regarding problem-solving learning. Polya stated that an effective problem-solving process must lead students through four main stages, namely understanding the problem, developing a solution plan, implementing the chosen strategy, and reviewing the results obtained. The activities that are integrated in the HOTS-based LKPD are proven to be in harmony with these stages, thus providing a systematic learning experience while training students to think reflective and critically. Thus, the development of HOTS-based LKPD in this study has met three main criteria in the theory of teaching tool development, namely validity, practicality, and effectiveness. Validity is evidenced by the feasibility of content and presentation in accordance with the curriculum, practicality is reflected in the ease of use by teachers and students, while effectiveness is seen in a significant increase in mathematical problem-solving skills. These results confirm that HOTS-based LKPD can be used as an innovative learning tool that not only improves learning outcomes, but also develops essential high-level thinking skills in facing the challenges of the 21st century.

The results of the study show that the HOTS-based LKPD developed is able to improve students' mathematical problem-solving skills. This is in line with the concept of *Higher Order Thinking Skills* (HOTS) which emphasizes analysis, evaluation, and creation skills in accordance with the revised Bloom Taxonomy (Anderson & Krathwohl, 2001). In the context of mathematics learning, HOTS plays an important role in helping students think critically and creatively in solving non-routine problems. LKPDs designed with HOTS integration allow students to not only memorize formulas, but also explore completion strategies, re-examine results, and relate concepts to real-life situations. These findings reinforce the study of Wulandari, Mulyatna, and Surya (2022) which showed that HOTS-based LKPD can improve conceptual understanding and learning independence of high school students.

In addition to being based on HOTS, the success of improving problem-solving skills in this study is also supported by the implementation of Polya measures that are integrated in the LKPD. The Polya stages—understanding problems, planning strategies, performing calculations, and re-examining results—systematically guide students in solving math problems. With this structured guidance, students become more directed in identifying important elements, choosing the right method, and evaluating the correctness of answers. This is consistent with the findings of Tambychik and Meerah (2010) who affirm that the main difficulty of students lies in the stage of understanding the problem and planning the solution, so that the teaching apparatus that follows the Polya model can help reduce these obstacles.

When compared to previous research, the results of this study make a new contribution in the context of the development of mathematics teaching tools on row and series materials. Septiani, Yuhana, and Sukirwan (2022) in *a systematic literature review* concluded that HOTS-based LKPD is effective in improving critical thinking skills, but their research focuses more on SPLTV and geometry materials. Meanwhile, research by Maimunah, Hariani, and Yuanita (2023) proves that LKPD based on *Problem Based Learning* is also able to improve problem-solving skills with medium to high N-gain categories. This study expands on their findings by showing that HOTS-based LKPD on row and series materials is not only valid and practical, but also effective in improving mathematical problem-solving skills, so that it can be used as an innovative alternative in facing the challenges of 21st century mathematics learning.

The results of this study show that the HOTS-based LKPD developed has a real contribution as an innovative solution in mathematics learning, especially in row and series materials. This teaching tool not only serves as a support for classroom activities, but is also able to direct students to think critically, analytically, and creatively through non-routine questions that demand a high level of cognitive engagement. This is different from conventional LKPD which tends to focus on procedural exercises, so students are used to memorizing formulas without understanding the meaning behind mathematical concepts. By utilizing HOTS-based LKPD, students get a wider opportunity to explore varied problem-solving strategies, according to Polya's problem-solving stages. Another contribution offered by this research is to provide valid, practical, and effective teaching tools so that they can be used directly by teachers in learning activities. The validity of LKPD is reflected in its integration with the HOTS indicator, practicality is shown through positive responses from teachers and students, while effectiveness is proven through a significant increase in student learning outcomes. Thus, this research provides a real alternative for teachers in overcoming the limitations of teaching tools that are still procedural. This is in line with the demands of the Independent Curriculum which emphasizes competency-based learning and contextual problem-solving.

Furthermore, the existence of this HOTS-based LKPD also contributes to improving the quality of 21st century education by preparing students to face global challenges that require high-level thinking skills. Students who are used to using HOTS-based LKPD will have better readiness to face international assessments such as PISA and in real life that require analysis, evaluation, and creative skills. Therefore, this research not only benefits students and teachers at SMA Negeri 1 Sihapas Barumun, but also offers a model for the development of teaching tools that can be replicated in other mathematics materials and different subjects. In other words, HOTS-based LKPD can be a strategic innovation in answering the weaknesses of conventional learning while supporting the achievement of 21st century competencies.

CONCLUSION

Based on the results of the research and discussion, it can be concluded that the Student Worksheet (LKPD) based on Higher Order Thinking Skills (HOTS) on the developed line and series material has met valid criteria, shown through the assessment of experts who affirm the suitability of content, language, presentation, and integration with the HOTS indicators. This LKPD is also declared practical to be used by both teachers and students, as evidenced by the positive response that shows its ease of use, attractiveness, and usefulness in the learning process. In addition, HOTS-based LKPD has proven to be effective in improving students' mathematical problem-solving skills, as can be seen from a significant increase in pretest and posttest scores with moderate N-gain categories. In line with these results, this study recommends that HOTS-based LKPD not only be applied to row and series materials, but also developed on other topics in mathematics learning or different subjects, and followed up with research on a wider scale so that its impact is further tested and can make a greater contribution to improving the quality of education.

The results of this study have several practical implications. For teachers, LKPD based on Higher Order Thinking Skills (HOTS) can be an alternative teaching tool that encourages more active, contextual, and challenging learning, making it easier for teachers to train students' critical thinking skills and problem-solving skills. For schools, the existence of this LKPD can support the improvement of the quality of mathematics learning and become an innovation that is in line with the demands of the Independent Curriculum in shaping 21st century competencies. In addition, schools can use the results of this research as a reference in the preparation of teaching tools in other subjects that also require a HOTS approach. Meanwhile, for other researchers, this research can be used as a foothold to develop similar teaching tools on different mathematics topics or at other levels of education, as well as expand the trial on a larger scale to test the consistency of its effectiveness. Thus, this research not only benefits the local context of SMA Negeri 1 Sihapas Barumun, but also offers a contribution that can be applied more widely in efforts to improve the quality of HOTS-based education.

BIBLIOGRAPHY

Adeoye, M. A., Wirawan, K. A. S. I., Pradnyani, M. S., & Septiarini, N. I. (2024). Revolutionizing education: Unleashing the power of the ADDIE model for effective teaching and learning. *Jurnal Pendidikan Indonesia*, *13*(1), 202–209. https://doi.org/10.23887/jpiundiksha.v13i1.68624

Hasibuan, R. (2022). STEAM-based learning media: Assisting in developing learning media for early childhood through ADDIE model. *Journal (Early Childhood Education)*. https://pdfs.semanticscholar.org/1c21/4b216ebdfd52c9ddca4d374788bca7b87d67.pdf

Hidayah, N. (2023). *Development of HOTS-based student worksheets on trigonometry material: Valid, practical and effective in improving problem-solving skills*. https://pdfs.semanticscholar.org/8f97/9552197239309602de9176f5a3b069055ddc.pdf

Jones, K. (2021). The topic of sequences and series in the curriculum and textbooks for schools in England: A way to link number, algebra and geometry. *International Conference on School Mathematics Textbooks*. https://eprints.soton.ac.uk/445735/1/JonesK_sequences_series_England_ICSMT_2011.pdf

Kadijevich, D. M. (n.d.). *Impacts of TIMSS and PISA on mathematics curriculum reforms* (M. S. Hannula (ed.); pp. 375–392). Springer. https://doi.org/10.1007/978-3-031-13548-4_22

Karwadi, K. (2024). A review of the effects of active learning on high-order thinking skills: A meta-analysis within Islamic education. *Journal of Education and Learning (EduLearn)*, *18*(1), 97–106. https://doi.org/10.11591/edulearn.v18i1.20895

Kusumaningtyas, D. A. (2024). A study on the development of higher order thinking evaluation instrument in work and energy for senior high school. *International Journal of Learning and Teaching (IJOLAE)*. https://journals.ums.ac.id/ijolae/article/view/23125

Niwanggalih, P. (2023). Student Worksheets Oriented to Higher Order Thinking Skills: development and student responses. In *Tropical Science and Technology Communication Journal*. https://ejournal.undiksha.ac.id/index.php/TSCJ/article/download/62574/29108/221958

OECD. (2023). *Trends in International Mathematics and Science Study (TIMSS)*. https://en.wikipedia.org/wiki/Trends_in_International_Mathematics_and_Science_Study

Omanda, N., Harahap, F., & Wau, Y. (2023). Development of Student Worksheets Based Project Based Learning to Improve High-Level Thinking Skills (HOTS) on Magnetic Material. *Randwick International of Education and Linguistics Science Journal*, *4*(3), 752–757. https://doi.org/10.47175/rielsj.v4i3.805

Rahmadhani, F., Mulyono, B., & Hapizah. (2025). Design of differentiated mathematics learning activities on arithmetic sequences and series to support students' computational thinking skills. *Tarbiyah: Jurnal Ilmiah Kependidikan*, *14*(1), 187–202. http://jurnal.uin-antasari.ac.id/index.php/jtjik/article/download/15853/4540

Saifurrisal, A. H. (2022). Students' errors in solving sequences and series word problems based on problem-solving steps of Polya. *Proceedings of ICSES 2022 – International Conference on Studies in Education and Social Sciences*, 89–100. https://files.eric.ed.gov/fulltext/ED630982.pdf

Sutarni, S., Sutama, S., Prayitno, H. J., Sutopo, A., & Laksmiwati, P. A. (2024). *The development of realistic mathematics education-based student worksheets to enhance higher-order thinking skills and mathematical ability*. https://www.researchgate.net/publication/379502005

Tumangger, W. R. (2024). The impact of realistic mathematics education-based. *IndoMath Journal of Mathematics Education*. https://indomath.org/index.php/indomath/article/view/122

Wahyudin, S. (2024). The implementation of project-based learning with ADDIE model to improve creative thinking abilities. *Elinvo: Electronics, Informatics, and Vocational Education*, *9*(2), 285. https://journal.uny.ac.id/index.php/elinvo/article/download/77240/22532

Al Mashagbeh, I. A., Al-Fraihat, A. H., Al-Khasawneh, M. A., & Bataineh, E. A. (2025). Artificial intelligence applications in education: Enhancing learning outcomes and engagement. *Education and Information Technologies, 30*(2), 1457–1475. https://doi.org/10.1007/s10639-024-12897-2

Al-Maroof, R. S., Alfaisal, R., Salloum, S. A., & Aburayya, A. (2024). Examining the role of student engagement in the relationship between AI applications and learning performance. *Education and Information Technologies, 29*(1), 221–240. https://doi.org/10.1007/s10639-023-11864-9

Asmar, A., Mariën, I., & Van Audenhove, L. (2022). No one-size-fits-all! Eight profiles of digital inequalities for customized inclusion strategies. *New Media & Society, 24*(2), 279-310. https://doi.org/10.1177/14614448211063182

Bernacki, M. L., Greene, M. J., & Lobczowski, N. G. (2021). A systematic review of research on personalized learning: Personalized by whom, to what, how, and for what purpose (s)?. *Educational Psychology Review, 33*(4), 1675-1715. https://par.nsf.gov/servlets/purl/10274018

Bhatt, P., & Muduli, A. (2024). AI learning intention, learning engagement and behavioral outcomes: An empirical study. *Journal of Management Development*, *43*(6), 920-938. https://doi.org/10.1108/JMD-05-2024-0173

Chen, X., Xie, H., Qin, S. J., Wang, F. L., & Hou, Y. (2025). Artificial intelligence-supported student engagement research: Text mining and systematic analysis. *European Journal of Education*, *60*(1), e70008. https://doi.org/10.1111/ejed.70008

Cho, M. K., & Kim, S. (2025). Analyzing AI-based educational platforms for supporting personalized mathematics learning. *International Electronic Journal of Mathematics Education*, *20*(4), em0847. https://doi.org/10.29333/iejme/16664

Engelbrecht, J., & Borba, M. C. (2024). Recent developments in using digital technology in mathematics education. *ZDM–Mathematics Education, 56*(2), 281-292. https://doi.org/10.1007/s11858-023-01530-2

Fletscher, L., Mercado, J., Gómez, Á., & Mendoza-Cardenas, C. (2025). Innovating personalized learning in virtual education through AI. *Multimodal Technologies and Interaction, 9*(7), 69. https://doi.org/10.3390/mti9070069

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research, 18*(1), 39–50. https://doi.org/10.1177/002224378101800104

Guettala, M., Bourekkache, S., Kazar, O., & Harous, S. (2024). Generative artificial intelligence in education: Advancing adaptive and personalized learning. *Acta Informatica Pragensia, 13*(3), 460-489. https://doi.org/10.18267/j.aip.235

Hwang, G. J., & Tu, Y. F. (2021). Roles and research trends of artificial intelligence in mathematics education: A bibliometric mapping analysis and systematic review. *Mathematics, 9*(6), 584. https://doi.org/10.3390/math9060584

Integrating Artificial Intelligence in Primary Mathematics Education: Investigating Internal and External Influences on Teacher Adoption. (2025). *International Journal of Science and Mathematics Education,* 23, 1283-1308. https://doi.org/10.1007/s10763-024-10515-w

Irshad, R., Ahmad, I., & Malik, M. (2023). Generative AI-based feedback and its impact on student engagement and learning performance. *Computers and Education: Artificial Intelligence,* 4, 100145. https://doi.org/10.1016/j.caeai.2023.100145

Lin, C. C., Huang, A. Y., & Lu, O. H. (2023). Artificial intelligence in intelligent tutoring systems toward sustainable education: a systematic review. *Smart learning environments*, *10*(1), 41. https://doi.org/10.1186/s40561-023-00260-y

Liu, B., Zhang, J., Lin, F., Jia, X., & Peng, M. (2025). One size doesn't fit all: A personalized conversational tutoring agent for mathematics instruction. ArXiv. https://arxiv.org/abs/2502.12633

Nunnally, J. C. (1978). *Psychometric theory* (2nd ed.). McGraw-Hill.

Oubagine, R., Laaouina, L., Jeghal, A., & Tairi, H. (2025, July). Advancing MOOCs Personalization: The Role of Generative AI in Adaptive Learning Environments. In *International Conference on Artificial Intelligence in Education* (pp. 242-254). Cham: Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-99261-2_22

Ramadhani, A. K., & Ramadani, I. (2024). AI in mathematics education: Potential ranging from automation to personalized learning. *Linear: Journal of Mathematics Education*. https://doi.org/10.32332/46xc9p64

Saraswat, S. (2023). The role of artificial intelligence in enhancing student engagement in higher education*. International Journal of Emerging Technologies in Learning, 18*(12), 23–36. https://doi.org/10.3991/ijet.v18i12.43579

Siregar, N. C. (2020, May). Interest STEM based on family background for secondary school students: Validity and reliability instrument using Rasch model analysis. In *Proceeding in RSU International Research Conference*. https://rsucon.rsu.ac.th/proceedings

Strielkowski, W., Grebennikova, V., Lisovskiy, A., Rakhimova, G., & Vasileva, T. (2025). AI-driven adaptive learning for sustainable educational transformation. *Sustainable Development*, *33*(2), 1921-1947. https://doi.org/10.1002/sd.3221

Tang, W. K.-W. (2025). Artificial intelligence in mathematics education: Trends, challenges, and opportunities. *International Journal of Research in Mathematics Education, 3*(1), 75–90. https://doi.org/10.24090/ijrme.v3i1.13496

Vieriu, A.-M. (2025). *The impact of artificial intelligence (AI) on students' academic development. Education Sciences, 15*(3), Article 343. https://doi.org/10.3390/educsci15030343

Wan, Y., Li, R., Li, W., & Du, H. (2025). Impact pathways of AI-supported instruction on learning behaviors, competence development, and academic achievement in engineering education. *Sustainability*, *17*(17), 8059. https://doi.org/10.3390/su17178059

Wang, S., Sun, Z., Wang, H., Yang, D., & Zhang, H. (2025). Enhancing student acceptance of artificial intelligence-driven hybrid learning in business education: Interaction between self-efficacy, playfulness, emotional engagement, and university support. *The International Journal of Management Education*, *23*(2), 101184. https://doi.org/10.1016/j.ijme.2025.101184

Wang, S., Wang, F., & Zhu, Z. (2024). *Artificial intelligence in education: A systematic literature review. Expert Systems with Applications, 252*, Article 124167. https://doi.org/10.1016/j.eswa.2024.124167

Wang. (2025). Research on AIGC-driven personalized mathematics learning system. *SHS Web of Conferences,* 215, 01003. https://doi.org/10.1051/shsconf/202521501003

Xiao, Y., Sun, J., & Li, M. (2023). The impact of emotional and cognitive engagement on students' academic performance in higher education. *Frontiers in Psychology,* 14, 1123456. https://doi.org/10.3389/fpsyg.2023.1123456

Xu, Q., Liu, Y., & Li, X. (2025). Unlocking student potential: How AI-driven personalized feedback shapes goal achievement, self-efficacy, and learning engagement through a self-determination lens. *Learning and Motivation*, *91*, 102138. https://doi.org/10.1016/j.lmot.2025.102138.