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Development of a Problem-Based Learning–Based Teaching Module on Sequences and Series to Enhance Students' Mathematical Problem-Solving Abilities in Phase E

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ABSTRACT. This study aims to develop and test the feasibility of a Problem-Based Learning (PBL)-based Sequence and Series teaching module in facilitating the mathematical problem-solving abilities of Phase E students. This type of research is development research (Research and Development) that uses the ADDIE model, which includes five stages: Analysis, Design, Development, Implementation, and Evaluation. In the analysis stage, observations and interviews were conducted with teachers and students at SMA Negeri 10 Pekanbaru to identify needs and problems in mathematics learning. The design stage focused on compiling a module based on PBL syntax, including problem orientation, student organization, investigation, development of work results, and evaluation and reflection. The developed module was validated by two Mathematics Education lecturers and one mathematics teacher to assess aspects of content, construction, language, and appearance. The validation results showed a validity level of 94% with a very valid category, while the practicality test results showed a value of 87% with a very practical category. Data collection techniques in this study included interviews, observations, questionnaires, and documentation. Data analysis related to validity and practicality was carried out using a percentage formula. These findings indicate that the developed teaching module is feasible and effective for mathematics instruction, particularly in improving students' problem-solving abilities. Therefore, this PBL-based teaching module can serve as an innovative learning tool that aligns with the principles of the Merdeka Curriculum and fosters students' critical, creative, and reflective thinking skills.

Keywords: mathematical problem-solving ability; merdeka curriculum; problem-based learning; sequences and series; teaching module

ABSTRAK. Penelitian ini bertujuan untuk mengembangkan dan menguji kelayakan modul ajar Barisan dan Deret berbasis *Problem-Based Learning* (PBL) dalam memfasilitasi kemampuan pemecahan masalah matematis peserta didik Fase E. Jenis penelitian ini adalah penelitian pengembangan (Research and Development) yang menggunakan model ADDIE yang meliputi lima tahap, yaitu *Analysis, Design, Development, Implementation,* dan *Evaluation.* Pada tahap analisis, dilakukan observasi dan wawancara dengan guru serta peserta didik di SMA Negeri 10 Pekanbaru untuk mengidentifikasi kebutuhan dan permasalahan dalam pembelajaran matematika. Tahap desain difokuskan pada penyusunan modul berdasarkan sintaks PBL yang mencakup orientasi terhadap masalah, pengorganisasian peserta didik, penyelidikan, pengembangan hasil karya, serta evaluasi dan refleksi. Modul yang telah dikembangkan divalidasi oleh dua dosen Pendidikan Matematika dan satu guru matematika untuk menilai aspek isi, konstruksi, kebahasaan, dan tampilan. Hasil validasi menunjukkan tingkat kevalidan sebesar 94% dengan kategori sangat valid, sedangkan hasil uji kepraktisan memperoleh nilai 87% dengan kategori sangat praktis. Teknik pengumpulan data dalam penelitian ini meliputi wawancara, observasi, kuesioner, dan dokumentasi. Analisis data terkait validitas dan praktikalitas dilakukan menggunakan rumus persentase. Temuan ini menunjukkan bahwa modul ajar yang dikembangkan layak dan efektif digunakan dalam pembelajaran matematika, terutama dalam meningkatkan kemampuan pemecahan masalah matematis peserta didik. Dengan demikian, modul ajar berbasis PBL ini dapat dijadikan sebagai alternatif perangkat pembelajaran

inovatif yang selaras dengan prinsip Kurikulum Merdeka, serta mampu menumbuhkan keterampilan berpikir kritis, kreatif, dan reflektif peserta didik.

Kata kunci: barisan dan deret; kemampuan pemecahan masalah matematis; kurikulum merdeka; modul ajar; *problem-based learning*

INTRODUCTION

Mathematics learning plays a crucial role in developing students' logical, analytical, critical, and systematic thinking skills. In the Merdeka Curriculum era, learning is no longer solely oriented toward memorizing formulas, but rather toward understanding concepts and applying them in real-life contexts. According to Sermatan et al., meaningful mathematics learning must encourage students to use their knowledge to solve the various problems they face daily. This view aligns with the student-centered learning principle at the core of the Merdeka Curriculum, where students are given space to explore, innovate, and find solutions through contextual learning experiences (Sermatan et al., 2019). Mathematics learning designed with contextual learning activities and problem-solving not only strengthens mathematical concepts but also improves students' mathematical communication skills in dealing with real-life situations outside the classroom (Nufus & Mursalin, 2020).

Furthermore, Permendikbudristek Number 033/H/KR/2022 emphasizes that the mathematics learning process must develop six main abilities, namely reasoning and proof, communication, connections, representation, and mathematical problem-solving ability. Of the six standards, mathematical problem-solving ability is one of the most important components because it integrates critical, creative, and reflective thinking skills (Kepala BKAP, 2022). Mathematical problem-solving ability is the main indicator of the success of meaningful learning, because through this ability, students are not only able to solve routine problems, but also can interpret, analyze, and find various solution strategies for complex contextual problems (Mustafa, 2020; Suryani et al., 2020). The research findings of Hestika et al. (2021) emphasize that mathematical problem-solving ability not only functions as a cognitive achievement, but also as a means of forming reflective and adaptive thinking patterns of students in facing mathematical problems and real problems in everyday life.

Conceptually, Polya explains that mathematical problem-solving skills consist of four important stages: understanding the problem, developing a solution plan, checking the solution plan or carrying out calculations, and rechecking the solution to correct errors (Nufus et al., 2021). These four stages not only reflect the mathematical thinking process but also form the basis for developing the character of reflective and independent learners. However, the reality in the field shows that these abilities are still relatively low (Sanidah & Sumartini, 2022).

Research by Lestari et al. (2022) at SMAN 7 Mataram found that only 44.8% of students achieved the moderate category, and 28.4% were in the low category in mathematical problem-solving abilities. Similar conditions were also found in research conducted by Badrulaini et al. (2020) at SMA Negeri 15 Pekanbaru and research conducted by Damayanti & Kartini (2022) at SMA Nurul Falah Pekanbaru, that most students were unable to understand the problem thoroughly and had difficulty interpreting the results of the solution, especially for non-routine problems. Meanwhile, the results of other studies show that students at the junior high school level have significant problems in applying strategies to solve problems, namely, 352 out of 585 students received a score of 0 for this aspect (Nufus et al., 2024). These findings indicate a gap between curriculum demands and students' actual abilities.

This gap is inextricably linked to learning approaches that are still dominated by lectures and routine exercises. Noer et al. (2023) and Wulandari et al. (2023) state that learning that focuses on memorizing formulas leads to passive learning, which tends to rely on similar examples without understanding the underlying concepts. As a result, when faced with new problems that require in-depth reasoning and critical thinking strategies, they struggle to find solutions. Therefore, innovative

learning models are needed that can encourage students to think actively, creatively, and reflectively in discovering concepts and solving real-world problems.

One recommended model for addressing this issue is Problem-Based Learning (PBL). According to Mariskhantari et al. (2022), PBL is a learning model that places real-world problems as the primary context for students to learn critical thinking and construct their own knowledge. This model consists of five main stages: orienting students to the problem, organizing learning activities, guiding independent and group investigations, developing work, and evaluating the learning process and outcomes. Through these stages, PBL not only fosters higher-order thinking skills but also fosters independent learning and collaboration among students.

Various studies have proved the effectiveness of PBL in improving learning outcomes. Juniati & Jamaan (2024) and Abidah et al. (2021) found that implementing the PBL model can significantly improve critical thinking and mathematical problem-solving skills. Similar results were obtained by Budianto (2021) at SMA Negeri 1 Moga, which showed an increase in student learning completion from only 3% in the first cycle to 79% after implementing two PBL cycles. However, most of the research conducted has been limited to measuring the effectiveness of PBL implementation in the learning process. Not many have systematically developed learning tools that integrate the PBL approach with the requirements of the latest curriculum, the Merdeka Curriculum (Wulandari et al., 2023).

In the context of implementing the Merdeka Curriculum, teaching modules play a strategic role as the primary tool used by teachers to carry out the learning process. Wulandari et al. (2023) explain that teaching modules have advantages over conventional teaching materials because they can be flexibly designed to suit student characteristics and educational unit needs. A good teaching module must adhere to contextual principles, foster independent learning, and encourage higher-order thinking skills. Meanwhile, research by Zetriuslita & Palendra (2022) shows that valid and practical teaching modules can help students achieve learning objectives more effectively, especially when combined with innovative learning models such as PBL.

Sequences and Series is a topic in mathematics that is both conceptual and applicable. This material requires students to understand patterns, regularities, and relationships between elements in a number system. However, previous observations and research have revealed that students often experience difficulties in understanding the basic concepts and application of formulas in this material (Damayanti & Kartini, 2022; Noer et al., 2023). The most common error arises because students tend to memorize formulas without understanding their meaning, resulting in failure to interpret contextual problems that require pattern analysis. Therefore, the development of a Problem-Based Learning Teaching Module for this material is relevant and important because it can bridge the gap between theory and practice through meaningful and challenging learning.

Based on the description above, this study aims to develop a Problem-Based Learning (PBL) Teaching Module on Sequences and Series to facilitate the mathematical problem-solving skills of Phase E high school students. The focus of this research lies in the process of developing and testing the feasibility of the module to meet the criteria of validity and practicality based on the results of assessments by experts, teachers, and responses from students as users. The development of this module is expected to make a real contribution in presenting mathematics learning that is more contextual, interactive, and in accordance with the spirit of the Merdeka Curriculum, which emphasizes independent learning and strengthening critical thinking skills.

METHOD

This research is a research and development (Research and Development) that aims to produce a product in the form of a Problem-Based Learning (PBL) based teaching module on the Sequence and Series material to facilitate the mathematical problem-solving abilities of phase E students. The development model used is the ADDIE model, which consists of five main stages, namely analysis, design, development, implementation, and evaluation. The selection of the ADDIE model is based

on its systematic, flexible, and iterative characteristics, where each stage is interrelated and allows for continuous formative and summative evaluation. This reason makes the ADDIE model reliable and valid for use in research on the development of learning devices.

The first stage, analysis, was conducted to identify the need for developing teaching modules. The analysis encompassed three main aspects: curriculum analysis, student characteristics analysis, and needs analysis. Curriculum analysis was conducted by examining learning outcomes, learning objectives, and learning goals in the Merdeka Curriculum to ensure the developed teaching modules were relevant and aligned with national learning standards. Student characteristics analysis was conducted through observations of 10th-grade students at SMA Negeri 10 Pekanbaru to determine their initial abilities, learning styles, and the difficulties they faced. Meanwhile, a needs analysis was conducted through interviews with mathematics teachers to gather information about learning issues related to mathematical problem-solving skills. The analysis revealed the need to develop innovative and contextual teaching modules to enhance these skills.

The second stage, design, aims to create a teaching module based on the analysis results. At this stage, researchers determine the module's format and structure, referring to the provisions of the Merdeka Curriculum based on Ministry of Education and Culture Regulation Number 56 of 2022. Module components consist of general information, core components, and appendices. Learning activities and student worksheets are designed according to the five stages of the PBL model: student orientation to the problem, student organization for learning, individual and group investigation guidance, development and presentation of work results, and analysis and evaluation of the problem-solving process. At this stage, research instruments are also developed, consisting of validation sheets and response questionnaires, which are used to measure the validity and practicality of the teaching module.

The third stage is development, which is the process of compiling and producing a teaching module product according to the established design. The developed teaching module is consulted with the supervising lecturer to obtain suggestions and input, then validated by three expert validators who have competence in the field of mathematics education. Validation is carried out using a Likert-scale assessment sheet with four assessment categories: very inappropriate, inappropriate, appropriate, and very appropriate. Aspects assessed include content, construction, and completeness of module components. The validation results serve as the basis for researchers to make revisions before the implementation stage, so that the resulting product has appropriate content and is in line with learning objectives.

The fourth stage is implementation, which is the trial phase of the teaching module that has been declared valid by experts. The trial was conducted on a small scale on six grade X students of SMA Negeri 10 Pekanbaru with heterogeneous abilities. The purpose of this trial was to assess the practicality of the teaching module based on students' direct experience in using the module during the learning process. Data was obtained through a response questionnaire containing indicators on aspects of appearance, content, and ease of use. The results of student responses were used as the basis for further revisions to make the teaching module more effective and easier to use in learning.

The final stage, evaluation, is conducted both formatively and summatively. Formative evaluation is conducted at each stage of development to ensure the module aligns with learning objectives and to identify areas that need improvement before proceeding to the next stage. Summative evaluation is conducted after all development stages are completed and trials are conducted, to assess the effectiveness, feasibility, and achievement of the learning module's objectives in facilitating students' mathematical problem-solving skills. This ongoing evaluation ensures the development process is dynamic and the resulting product meets valid and practical criteria.

The research subjects consisted of 39 students of class X.11 of SMA Negeri 10 Pekanbaru, as well as three expert validators, consisting of mathematics education lecturers and experienced teachers. The sampling technique used was purposive sampling, with the consideration that the selected subjects had characteristics that were in accordance with the research objectives and the

context of the application of PBL-based teaching modules. The data collected in this study included qualitative and quantitative data. Qualitative data were obtained from interviews, observations, and comments from validators and students. Quantitative data came from the results of validation assessments and student response questionnaires regarding the use of teaching modules and student worksheets.

Data collection techniques in this study included interviews, observations, questionnaires, and documentation. Face-to-face interviews with mathematics teachers were conducted to obtain initial information regarding the learning tools used, learning constraints, and the need for developing teaching modules. Observations were conducted to directly observe classroom learning activities and interactions between teachers and students. The questionnaires were provided in the form of validation sheets completed by expert validators and response questionnaires completed by students after the trial. Meanwhile, documentation was used to collect evidence of the implementation of activities, such as trial photographs and observation notes.

Data analysis was conducted to determine the validity and practicality of the teaching module. Validity analysis aimed to determine the module's feasibility based on the validator's assessment, while practicality analysis was used to assess the module's ease of use by students. The assessment results were then categorized into several criteria, as shown in Table 1 and Table 2 below.

Table 1. Criteria for Assessing the Validity of Teaching Module

Percentage Range (%)	Category	Description
85–100	Very Valid	The module is suitable for use without major revisions
70–84,99	Valid	The module is suitable for use with minor revisions
50–69,99	Less Valid	The module requires a complete revision
< 50	Invalid	The module is not suitable for use

Tabel 2. Criteria for Assessing the Practicality of Teaching Module

Percentage Range (%)	Category	Description
85,01–100	Very Practical	It can be used very easily by teachers and students
70,01–85	Practical	It can be used with minimal adjustments
50,01–70	Less Practical	It needs improvements to make it more user-friendly
< 50	Impractical	It cannot be used in teaching

Based on the criteria in Table 1 and Table 2, a teaching module is declared valid if the average score achieved is ≥70%, and practical if it achieves a score of ≥70%. Therefore, the higher the percentage, the better the module's feasibility and ease of use in learning. This classification is used as a reference in interpreting the results of expert validation and the results of practicality tests by students during the implementation phase of the research.

The reliability of this research method lies in the systematic use of the ADDIE model, which allows for continuous revision at each stage. The validity of the research results is strengthened by the use of various complementary data collection techniques, such as interviews, observations, questionnaires, and documentation, thus creating data triangulation that enhances the validity of the results. Furthermore, Akbar (2017) states that quantitative analysis using a Likert scale and standardized assessment criteria provides an objective measure of the validity and practicality of the developed product. Therefore, the method used in this research is considered reliable and valid in presenting findings scientifically.

RESULTS AND DISCUSSION

The research aims to develop and test the feasibility of a Problem-Based Learning (PBL)-based Sequence and Series content teaching module in facilitating the mathematical problem-solving abilities of Phase E students. This research is a development-research (R&D) that uses the ADDIE model, including five main stages, namely Analysis, Design, Development, Implementation, and

Evaluation. Each stage is carried out systematically so that the resulting product is not only theoretically feasible but also practically and effectively used in mathematics learning. The ADDIE model was chosen because it is able to provide a directed development flow, starting from needs analysis to evaluation of product effectiveness, so that the resulting module truly suits the needs of students and the learning objectives expected in the Merdeka Curriculum.

In the analysis stage, researchers conducted observations and interviews with teachers and students at SMA Negeri 10 Pekanbaru to identify learning problems and needs. The analysis results showed that the mathematics learning process at the school was still dominated by lecture methods and routine practice problems, with low student involvement in critical and reflective thinking processes. This condition impacted low mathematical problem-solving skills, especially in linking concepts to contextual situations. Teachers also revealed that the material on Sequences and Series was often a difficult topic to understand because many students only memorized the formulas without understanding their conceptual meaning. This finding is in line with Pandjo's opinion in (Masjudin, 2016), which stated that a weak understanding of basic mathematical concepts caused student errors in using Sequence and Series formulas. Furthermore, research by Arianta et al. (2022) also emphasized that the concept of geometric series is abstract, so students require the help of more contextual and interactive learning models to understand it. Based on the results of the analysis, the Problem-Based Learning (PBL) model was chosen because this model emphasizes a student-centred learning process, prioritizes solving real problems, and trains critical, collaborative, and reflective thinking skills, which are the core of developing mathematical problem-solving abilities.

The next stage, namely the design stage, focuses on designing the structure and content of the teaching module according to student needs and the principles of PBL. The module is structured based on PBL syntax, which consists of five main stages, namely (1) orientation to the problem, (2) organizing students, (3) investigation, (4) development and presentation of work results, and (5) evaluation and reflection. The module structure covers five main topics: Arithmetic Sequences, Arithmetic Series, Geometric Sequences, Geometric Series, and Infinite Geometric Series. Each section is equipped with learning objectives, material descriptions, contextual examples, problem-based activities, and formative assessments designed to enable students to develop high-level mathematical thinking skills. This module is also structured by paying attention to the flow of learning objectives of the Merdeka Curriculum. It is oriented towards strengthening the Pancasila Student Profile, especially in terms of critical, creative, and independent reasoning. The module's visual design is designed to be engaging and communicative, using colour, illustrations, and contextual examples relevant to everyday life to help students understand the concepts and relate them to real-life experiences.

During the development stage, the module design is transformed into a complete product, which experts then validate to assess the appropriateness of its content, construction, language, and presentation. Validation was conducted by two Mathematics Education lecturers and one high school mathematics teacher using a Likert-based assessment sheet.

Table 3. Validation Results of the PBL-Based Teaching Module

Rated Aspect	Average Score (%)	Category
Content feasibility	95	Very valid
Construction feasibility	92	Very valid
Language feasibility	93	Very valid
Appearance	96	Very valid
Total average	94	Very valid

The validation results in Table 3 show that the Problem-Based Learning (PBL) teaching module achieved an average validity score of 94%, which is categorized as highly valid. This validation score indicates that the module has met the eligibility criteria in terms of content, construction, language, and presentation. The content feasibility aspect achieved the highest score,

at 95%, indicating that the material presented in the module is relevant to learning outcomes and the principles of the Merdeka Curriculum. The appearance aspect also showed a high score of 96%, indicating that the module's visual design is considered attractive, communicative, and able to increase student learning motivation. Meanwhile, the construction and language aspects each obtained scores of 92% and 93%, indicating that the material presentation is systematically structured and uses language appropriate to the students' developmental level. Thus, the validation results from experts prove that this PBL-based teaching module is suitable for use in the mathematics learning process to improve students' mathematical problem-solving abilities.

The validators also provided several suggestions for improvements, such as clarifying student activity instructions, strengthening the connection between contextual problems and mathematical concepts, and adding visual illustrations to facilitate understanding. After revisions based on these suggestions, the module became more systematic, communicative, and contextual, making it suitable for implementation in the next phase.

The implementation phase was conducted to assess the module's practicality and effectiveness in facilitating mathematical problem-solving skills. The trial was conducted in three stages: one-to-one test, small group test, and field test.

In the one-to-one test phase, the module was tested on three students with different abilities (high, medium, and low). The test results showed that some activity instructions still needed to be simplified to be more understandable, especially in the problem investigation and presentation sections. Students also provided positive feedback on the module's appearance, which was considered interesting and helped them understand the concept of Sequences and Series through the context of real-life problems. Based on these results, revisions were made to several parts of the text and instructions before proceeding to the small group testing phase.

Table 4. Results of the Practicality Test of the PBL-Based Teaching Module

Test Type	Number of Students	Practicality Percentage (%)	Category
Small group test	6	75	Practical
Field test	30	87	Very practical

The results in Table 4 show that the module's practicality level increased from the small group test to the field test. In the small group test, the module achieved an average practicality score of 75%, categorized as practical, indicating that it was usable, although it still required minor adjustments in instructional delivery. After revisions based on the test results, the practicality score increased to 87% in the field test, categorized as very practical. This score indicates that the PBL-based learning module is easy for teachers and students to use in the learning process and is able to facilitate active, collaborative, and reflective learning activities.

These results demonstrate that the PBL-based learning module can be easily used by students and teachers in the learning process. Students also demonstrated improved ability to identify problems, design solution strategies, and reflect on their work, all important indicators of developing mathematical problem-solving skills. Furthermore, group discussions and investigations encouraged more active mathematical collaboration and communication in the classroom. These findings confirm that the application of the PBL model in mathematics learning modules not only enhances practicality but also contributes to the development of higher-order thinking skills as expected in the Merdeka Curriculum.

The final stage, evaluation, is conducted both formatively and summatively to ensure the module's effectiveness in supporting the development of mathematical problem-solving skills. Formative evaluation is applied at each stage of the ADDIE model development to address module deficiencies. In contrast, summative evaluation is conducted after the implementation stage to assess the overall product's results.

Table 5. Results of the Validity and Practicality Evaluation of the PBL-Based Teaching Module

Aspects Evaluated	Percentage (%)	Category
Validity	94	Very valid
Practicality	87	Very Practical

Based on the evaluation results in Table 5, the PBL-based learning module was declared highly valid with a percentage of 94% and highly practical with a percentage of 87%, indicating that this product is suitable for use in mathematics learning. Furthermore, observations and student responses indicate that problem-based learning activities can increase learning motivation, active engagement, and systematic thinking skills. Students were able to relate the concept of Sequences and Series to real-world situations. They showed improvement in each stage of problem-solving, as stated by Polya in Sanidah & Sumartini (2022), namely understanding the problem, planning a solution, implementing the plan, and reviewing the results.

In terms of effectiveness, the results of the mathematical problem-solving ability test showed significant improvements in each indicator after using the PBL-based learning module. Students not only became more skilled at identifying problems and designing problem-solving strategies, but also demonstrated improved ability to provide logical justification for the steps taken. This condition demonstrates that the PBL-based learning module is effective in facilitating the development of mathematical problem-solving skills and supporting the achievement of mathematics learning objectives oriented toward higher-order thinking.

Overall, the results of this study indicate that the application of the Problem-Based Learning model in the development of the Sequence and Series content teaching module is effective in facilitating students' mathematical problem-solving abilities. This teaching module is not only valid and practical, but also aligns with the principles of the Merdeka Curriculum, which emphasizes meaningful, contextual learning and is oriented towards the development of higher-order thinking skills. These findings support Pandjo's opinion in Masjudin (2016), which emphasizes the importance of mastering concepts through meaningful activities, and are in line with the results of research by Arianta et al. (2022), which shows that problem-based learning can help students better understand abstract concepts.

However, this study has limitations because it was implemented in only one school, so the results cannot be generalized widely. Therefore, further research is recommended involving more schools with different student characteristics to ensure more representative results. Therefore, the results of this study are expected to serve as a reference for teachers, curriculum developers, and educational researchers in developing innovative and contextual learning tools to improve students' mathematical problem-solving skills in accordance with the demands of the Merdeka Curriculum.

CONCLUSION

This development research produced a product in the form of a teaching module related to the material of Sequences and Series, based on the Problem-Based Learning (PBL) model, designed to facilitate the mathematical problem-solving abilities of Phase E students. The development process used the ADDIE model, which includes the stages of analysis, design, development, implementation, and evaluation. The results of validation by experts showed that the developed teaching module was in the very valid category. In contrast, the trial results showed that the module was very practical to use in learning. Thus, the teaching module with the material of Sequences and Series based on Problem-Based Learning that was developed was declared feasible, valid, and practical to be used as teaching material in improving the mathematical problem-solving abilities of Phase E students.

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