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DEVELOPMENT OF PROBLEM-BASED LEARNING WORKSHEETS ON SEQUENCES AND SERIES TO FACILITATE STUDENTS' MATHEMATICAL CREATIVE THINKING SKILLS

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ABSTRACT The ability to think creatively in mathematics is a crucial aspect of learning, yet evidence shows that students' creative mathematical thinking skills, particularly in the topic of Sequences and Series, remain low. One solution to address this issue is through the use of Problem-Based Learning (PBL)-based Student Worksheets. This research aims to develop a valid and practical Student Worksheet. The study follows the 4D development model, consisting of the stages: define, design, develop, and disseminate. The instruments used for data collection were validation sheets and practicality questionnaires. Analysis of the validation sheet data showed that the Student Worksheet was categorized as highly valid, with an average percentage of 93.73%. Similarly, the practicality questionnaire analysis indicated that the Student Worksheet was rated as practical, with an average percentage of 83.77%. Therefore, the developed Student Worksheet meets the criteria of validity and practicality and can be used effectively in learning activities. The implication of this research is that it allows students to independently build knowledge in mathematics, facilitating their creative mathematical thinking skills.

Keywords: problem-based learning, mathematical creative thinking skills, sequences and series, student worksheet.

ABSTRAK Kemampuan berpikir kreatif dalam matematika merupakan aspek penting dalam pembelajaran, namun fakta menunjukkan bahwa kemampuan berpikir kreatif matematis siswa, terutama pada topik Barisan dan Deret, masih rendah. Salah satu upaya untuk mengatasi masalah ini adalah dengan menggunakan Lembar Kerja Peserta Didik (LKPD) berbasis Problem-Based Learning (PBL). Penelitian ini bertujuan untuk mengembangkan LKPD yang valid dan praktis. Penelitian ini menggunakan model pengembangan 4D yang terdiri dari tahap define, design, develop, dan disseminate. Instrumen yang digunakan untuk pengumpulan data adalah lembar validasi dan angket kepraktisan. Analisis data lembar validasi menunjukkan bahwa LKPD dikategorikan sangat valid dengan persentase rata-rata

93,73%. Analisis data angket kepraktisan menunjukkan bahwa LKPD dikategorikan praktis dengan persentase rata-rata 83,77%. Dengan demikian, LKPD yang dikembangkan dalam penelitian ini telah memenuhi persyaratan validitas dan kepraktisan serta dapat digunakan dalam kegiatan pembelajaran. Implikasi dari penelitian ini adalah memudahkan siswa untuk membangun pengetahuan secara mandiri dalam pembelajaran matematika sehingga kemampuan berpikir kreatif matematis siswa dapat difasilitasi.

Keywords: PBL, kemampuan berpikir kreatif matematis, baris dan deret, lembar kerja peserta didik.

INTRODUCTION

Mathematics plays a crucial role in enhancing human resources by providing tools for problem-solving and critical thinking. According to Damayanti & Afriansyah (2018), mathematics serves as a medium to assist students in achieving the expected competencies. After studying mathematics, students are expected to master predetermined competencies. As noted by Sumarmo (2013) and Afriansyah (2016), mathematics is an activity that reflects human thought processes, helping students develop creative and independent problem-solving skills.

Suyanto, as cited by Jihad (2013), emphasizes that students must be able to think independently and creatively to meet various challenges, improve their quality of life, and effect positive change. Creativity, according to Arnyana (2018), refers to the ability to generate novel or distinctive ideas. Students who can think creatively in mathematics will have an easier time solving problems systematically and inventively. However, it is evident that many students have not fully developed their creative mathematical thinking skills.

In line with Sumarmo (2013), mathematical creative thinking can be measured through four key indicators: (1) Fluency, the ability to produce numerous ideas, answers, or approaches; (2) Flexibility, the ability to view problems from various perspectives and adapt strategies accordingly; (3) Originality, the capacity to generate unique and innovative solutions; and (4) Elaboration, the ability to enrich and expand ideas or concepts by providing detailed explanations.

One important topic that high school students must master is Sequences and Series. This includes arithmetic and geometric sequences, infinite geometric sequences, and applying these concepts to problems such as simple and compound interest. However, students often struggle with understanding and applying the material. As Silaban et al. (2022) point out, students frequently experience difficulty when solving problems related to Sequences and Series. Septiahani et al. (2020) found that 84.5% of students make errors in transforming these problems into mathematical models. These challenges prevent students from fully exploring and developing their creative thinking skills, particularly in finding and understanding the nth term of sequences.

Moreover, observational data from SMAN 1 Rambah, Riau Province, show that students still struggle to answer questions correctly, fail to provide alternative

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solutions, and lack originality in their responses. Many do not structure their solutions in a systematic manner, which prevents them from meeting the learning objectives established by their teachers. A teacher-centered approach further exacerbates this issue, as students tend to passively follow instructions without fully understanding the content. To address these problems, teachers must create learning environments that encourage students to use critical thinking and problem-solving skills.

One effective way to facilitate active student engagement and creative problem-solving is through the use of the Problem-Based Learning (PBL) model. PBL starts by presenting students with real-life, open-ended problems that encourage them to explore multiple solutions and ideas. This approach allows students to actively develop their mathematical creative thinking skills. Lestari (2018) describe five stages in the PBL model: (1) introducing students to the problem, (2) organizing students to learn through group work, (3) guiding investigation and exploration, (4) developing solutions, and (5) presenting and reflecting on solutions. These stages provide a structured process for developing students' creative thinking abilities.

Several studies have demonstrated the effectiveness of the PBL model in enhancing students' creative thinking. Research by Azmi et al (2014) found that PBL significantly improves the creative thinking skills of seventh-grade students. Similarly, Happy and Widjajanti (2014) showed that PBL is effective in fostering both critical and creative mathematical thinking, as well as boosting students' self-esteem. Additionally, Subianto, Silviani, and Zubainur (2018) found that students used imaginative approaches to problem-solving within the PBL framework, leading to improved creative thinking abilities.

However, one factor hindering the development of students' creative thinking skills is the lack of worksheets designed around the PBL model. Traditional worksheets often do not provide the opportunities for exploration and conceptual understanding that PBL encourages. This reduces student engagement and limits the development of critical thinking skills. Therefore, it is essential to design worksheets that align with the PBL model to foster students' mathematical creative thinking.

This study aims to develop Student Worksheets based on the PBL model, specifically targeting the topic of Sequences and Series, to help students enhance their mathematical creative thinking skills. The final product is expected to provide a reference for teachers in designing PBL-based worksheets that maximize student engagement and foster creative problem-solving. Student Worksheets are valuable teaching tools that facilitate independent learning by guiding students through activities and promoting engagement. Yulianti et al. (2015) suggest that worksheets can foster active learning, process skills, and motivation. PBL-based worksheets designed to focus on creative thinking can increase students' problem-solving abilities and their overall enthusiasm for learning.

The researchers created Rows and Sequences worksheets based on Problem Based Learning that can help Phase E students improve their mathematical creative thinking abilities. Validators verified the developed learning tools. In addition, Phase E students were subjected to the Student Worksheet for testing in order to gather data regarding its applicability. In the Indonesian context, Phase E refers to students in grades 10 to 12 of senior high school (SMA or equivalent), as classified in the Kurikulum Merdeka. At this stage, students are expected to engage in more complex and critical learning activities, focusing on deepening their problem-solving skills, creativity, and independence in tackling mathematical and real-life challenges. Therefore, the Student Worksheets developed in this study are designed to meet the needs of Phase E students in fostering these advanced learning capabilities.

METHODS

This study utilizes the research and development (R&D) method, specifically employing the 4D model, which consists of four stages: define, design, develop, and disseminate. According to Arywiantari et al. (2015), the 4D model is effective for developing learning tools, as it allows a systematic approach in creating educational resources. Sugiyono (2009) further explains that R&D is a research method aimed at developing a particular product and testing its effectiveness. In this research, the product developed is a Student Worksheet based on Problem-Based Learning (PBL) for the topic of Sequences and Series, designed to enhance the mathematical creative thinking skills of Phase E students, and tested for its validity and practicality.

In the define stage, several analyses are conducted: end-to-end analysis, learner analysis, concept analysis, task analysis, and the specification of learning objectives. The end-to-end analysis identifies the main issues in developing the Student Worksheet by conducting a literature review and analyzing test results. Learner analysis focuses on the characteristics, abilities, and experiences of Phase E students, aligned with the independent curriculum. Task analysis refers to learning outcomes for 10th-grade Phase E students on Sequences and Series, based on BSKAP No. 033/H/KR/2022. Concept analysis determines the content of the material to be included in the Student Worksheet, referring to textbooks, teacher manuals, and the BSKAP Kemendikbudristek 2022 independent curriculum guide. Learning objectives are formulated based on the goals to be achieved after using the developed product.

Based on the define stage, the design stage involves preparing criteria tests, selecting formats and media, and creating the initial design of prototype 1 for the PBL-based Student Worksheet on Sequences and Series material. In the develop stage, the Student Worksheet was developed to improve Phase E students' mathematical creative thinking skills. Three experts validated the worksheet, and revisions were made based on their feedback to meet validity requirements.

Once validated, the worksheet proceeded to the one-on-one evaluation stage with three students at SMAN 1 Rambah, assessing readability and gathering feedback.

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After revisions, a small group test was conducted with six 10th-grade students (two high-achieving, two average, and two low-achieving) to refine usability. Following further revisions, a large group trial involved 36 students from class X SMAN 1 Rambah. A practicality questionnaire was administered at the final stage to assess the Student Worksheet's practicality, in line with Tinja's (2017) research, which recommends using student questionnaires to evaluate teaching materials' readability.

Data were collected using validation and student response sheets. The validation sheet, used in the expert review stage, employed both a Likert scale (1-4) and a Guttman scale (0-1) based on facial, content, and construct aspects. According to Akdon & Riduwan (2015), a Student Worksheet is valid if its validity percentage falls between 60-80% (valid category) or 80-100% (very valid). Student response questionnaires, used in the small group and field tests, assessed the product's readability and practicality. The product is considered practical if student response percentages fall between 70-85% or 85-100%, as outlined in Table 1 and Table 2 (Ramdani, 2014).

Table 1. Criteria for Validity Level

Value Range (%)	Interpretation
80% < N ≤ 100%	Very Valid
60% < N ≤ 80%	Valid
40% < N ≤ 60%	Valid Enough
20% < N ≤ 40%	Less Valid
0% < N ≤ 20%	Invalid

Tabel 2. Practicality Assessment Criteria

Value Range (%)	Interpretation
85% < N ≤ 100%	Very Practical
70% < N ≤ 85%	Practical
50% < N ≤ 70%	Less Practical
0 % < N ≤ 50%	Not Practical

FINDING AND DISCUSSION

The product was developed using the 4D model, as outlined in the research method. The 4D model consists of four stages: define, design, develop, and disseminate. The following are the findings from each stage of the development:

In the define stage, the initial focus was to identify key problems in mathematics learning and find suitable solutions. Through an initial-end analysis, based on data from the literature review and test results, it was revealed that students'

mathematical creative thinking skills were low, with an average score of 54%, especially in relation to rows and sequences. This aligns with findings by Rahmawati (2017) and Sutrimo (2019), who observed similar challenges in students' creative mathematical thinking. Additionally, it was noted that Student Worksheets were rarely used, and no Problem-Based Learning (PBL)-based Student Worksheets existed for rows and sequences that could help students develop creative mathematical thinking. This gap led to the need for developing worksheets to enhance students' creative thinking skills.

A student analysis was conducted to examine student characteristics, abilities, and learning interests. The study targeted Phase E students, typically aged 15-17, who are described by Piaget as being in the formal operational stage, capable of abstract reasoning, creative thinking, and logical calculations. Observations at SMA Negeri 1 Rambah revealed that students displayed enthusiasm when directly involved in problem-solving activities and group discussions. Moreover, students expressed a preference for visually engaging materials, leading to the design of Student Worksheets with appealing colors and images.

Next, a task analysis was performed. This involved creating a profile of Pancasila students according to the independent curriculum and establishing learning outcomes for rows and sequences, based on BSKAP No. 033/H/KR/2022. The concept analysis was carried out to outline relevant content for the independent curriculum, including arithmetic sequences, geometric sequences, arithmetic series, geometric series, infinite geometric series, simple interest, and compound interest. From this, 12 learning objectives were formulated to cover 15 JP (hours) of lessons. These objectives served as a guide for developing the content of the Student Worksheets.

In the design stage, the focus shifted to preparing validity and practicality instruments to assess the Student Worksheet, choosing a format aligned with the PBL model, and selecting appropriate media. The Student Worksheet was structured according to the five stages of the PBL model: problem orientation, organizing learning, guiding investigations, presenting work, and evaluating problem-solving. Each Student Worksheet consisted of five subtopics related to rows and sequences, adhering to BSKAP No. 033/H/KR/2022. The design also included:

1. Student Worksheet Cover: containing the identity of the worksheet, student information, learning objectives, and instructions for use.
2. Content: structured according to the PBL model to foster active learning and problem-solving.
3. Conclusion and Practice: sections requiring students to summarize concepts and complete additional practice problems.

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In the develop stage, expert validation was conducted based on face, content, and construct aspects. Validators completed a validation sheet, evaluating specific categories for each aspect. Suggestions and input from validators were incorporated into the revised Student Worksheets to improve their effectiveness before testing. The validation scores were highly favorable: 92.5% for Student Worksheet-1, 91.87% for Student Worksheet-2, 94.09% for Student Worksheet-3, 94.51% for Student Worksheet-4, and 94.96% for Student Worksheet-5, placing all worksheets in the "very valid" category. Overall, the average validation score across all worksheets was 93.73%, confirming the high validity of the PBL-based Student Worksheets for rows and sequences. As Dharmono (2018) notes, expert validation is crucial before product trials.

Table 3. Results of Student Worksheet Validation Analysis

Student Worksheet	Face Validity (%)	Content Validity (%)	Construct Validity (%)	Average (%)	Category
Student Worksheet 1	95.37	92.26	89.88	92.5	Very Valid
Student Worksheet 2	97.22	87.91	90.47	91.87	Very Valid
Student Worksheet 3	95.37	94.64	92.26	94.09	Very Valid
Student Worksheet 4	97.22	94.64	91.66	94.51	Very Valid
Student Worksheet 5	97.22	95.83	91.84	94.96	Very Valid
Average (%)	**96.48**	**93.05**	**91.66**	**93.73**	**Very Valid**

Table 3 presents the results of the Student Worksheet validation analysis, showing the ratings from the validators for face, content, and construct validity across five worksheets. The average rating of 93.73% indicates that the worksheets fall into the "Very Valid" category.

In addition to the validation process, student feedback was collected through a one-on-one evaluation. This evaluation involved three students from class X at SMAN 1 Rambah. As noted by Riefani (2019), readability testing helps identify sections of the Student Worksheet that may require revision and ensures clarity of the material. The evaluation was conducted over an 80-minute period to assess the readability of the worksheets. After completing the worksheets, students participated in unstructured interviews to provide feedback and suggest revisions for further testing. In Student Worksheet-2, some students found the sentence structure of one of the problems difficult to understand. Based on their suggestions, revisions were made to simplify the language for better clarity. Additionally, in Student Worksheet-1, there were typographical errors in some of the questions, which were also revised for accuracy.

These revisions improved the overall readability and ease of understanding for the students.

After these revisions, a small group trial was conducted with six heterogeneous class X students from SMAN 1 Rambah. Following their work on the Student Worksheets, the students completed a practicality instrument to evaluate the worksheets. Results from the small group trial showed that some students still had difficulty understanding certain problem sentences, leading to further revisions. The average practicality score for this trial was 83.77%, which is categorized as "Practical." Students commented that the worksheets were interesting, easy to understand, and that both the writing and images were clear and legible. This aligns with Asyhari et al. (2017), who noted that students tend to be more engaged when the content and media they interact with are more visually appealing.

The next phase involved a large group trial with 36 students from class X at SMAN 1 Rambah, incorporating students of varying abilities. After implementing the revisions from the small group trial, the average practicality score increased to 87.22%, placing the worksheets in the "Very Practical" category. As Arsyad (2006) suggests, learning media are effective in clarifying messages and information, thereby enhancing the learning process. Students in the large group trial confirmed that the worksheets were easy to understand, motivated them to learn, and were clearly legible.

Students expressed in the comments and suggestions section of the practicality questionnaire that the developed Student Worksheet helped them better understand the topic of sequences and series. They were enthusiastic about working on the worksheet and appreciated its attractive appearance. Some students suggested increasing the space provided for writing answers to enhance their learning experience. These comments and suggestions are illustrated in Figure 1.

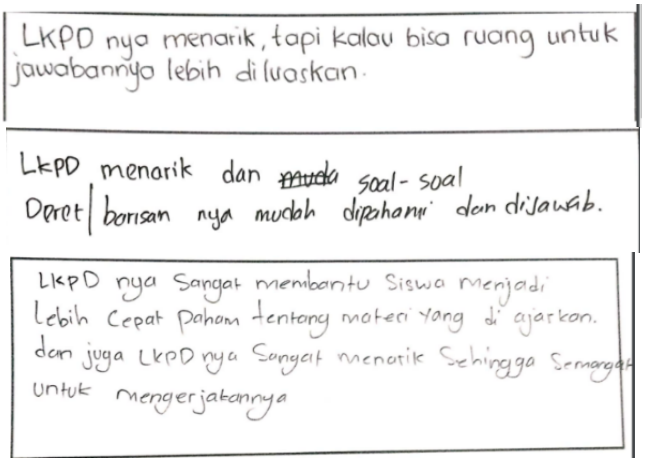

Figure 1. Comments and suggestions from the practicality questionnaire

After packaging the worksheet into a book, it was distributed to the school. The aim is for the Student Worksheet to assist teachers in developing their own materials

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and to simplify the implementation of learning. Each activity within the worksheet is designed according to the Problem-Based Learning (PBL) model and targets aspects of mathematical creative thinking skills identified during the research process. These activities include presenting problems in contexts familiar to students, encouraging them to comprehend problems thoroughly to express ideas and explore various problem-solving approaches, providing opportunities to voice opinions and engage in group discussions to generate numerous ideas and methods, and guiding them to utilize information to solve problems and reach logical conclusions.

The development of PBL-based worksheets on the topic of sequences and series has met the criteria for being very valid and very practical, making them suitable for classroom use or as references. However, since this subject is typically taught in odd semesters and the research was conducted in even semesters, the effectiveness of the worksheets has not yet been measured. Additionally, the primary objective of this study was to assess the product's practicality and validity. Some limitations arose due to the researchers' limited experience in creating PBL-based worksheets that effectively promote students' mathematical creative thinking skills. Therefore, researchers intending to develop high-quality PBL-based worksheets should deepen their understanding of each development step and the characteristics of such worksheets that facilitate students' creative mathematical thinking abilities.

CONCLUSIONS AND RECOMMENDATIONS

Based on the research results, it can be concluded that the product developed is a Problem-Based Learning (PBL) worksheet on the topic of sequences and series, designed to enhance the creative mathematical thinking skills of Phase E students in grade X of high school. The four-dimensional (4D) development model was used in this study, and after going through trials and validation stages, the developed worksheet was deemed valid and practical. Therefore, the sequence and series worksheet based on the PBL model is considered suitable to help Phase E students develop their creative mathematical thinking skills. This worksheet can serve as a reference for other researchers who wish to develop worksheets with different materials, learning models, or skills. The researchers also recommend that future studies measure the effectiveness of the worksheets in improving student learning outcomes, in addition to assessing their validity and practicality.

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