

THE DEVELOPMENT OF PROBLEM BASED LEARNING ANDROID-ASSISTED E-WORKSHEET TO IMPROVE STUDENTS' MATHEMATICAL CREATIVE THINKING

Upik Haryono¹, Euis Eti Rohaeti², Asep Ikin Sugandi³

¹IKIP Siliwangi, Jl. Terusan Jend. Sudirman, Cimahi, Indonesia.
upikharyono03061980@gmail.com

²IKIP Siliwangi, Jl. Terusan Jend. Sudirman, Cimahi, Indonesia.
e2rht@ikipsiliwangi.ac.id

³IKIP Siliwangi, Jl. Terusan Jend. Sudirman, Cimahi, Indonesia.
asepikinsugandi@ikipsiliwangi.ac.id

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ABSTRACT

Mathematical creative thinking ability refers to a student's capacity to solve problems, integrate existing knowledge and skills, and generate new ideas based on key concepts. However, observations in the field indicate that students' mathematical creative thinking abilities remain relatively low. This study aims to determine the effectiveness of a Problem-Based Learning (PBL)-based Electronic Student Worksheet (E-Worksheet) in improving elementary school students' mathematical creative thinking, supported by an Android application called Bangun Ruang Sisi Datar (Bangsidat). The PBL model, assisted by the Bangsidat Android application, is designed to enhance students' creative mathematical thinking skills. Thus, the primary objective of this research is to develop an Android-based student worksheet that supports this goal. The method used in this study is Design Research, which consists of two main stages: planning design and formative evaluation design. The research subjects were 28 eighth-grade students from SMP Negeri 2 Haurgeulis, located in the Haurgeulis Subdistrict of Indramayu Regency. Data collection instruments included attitude scales, interviews, documentation, and problem-solving tests. The collected data were analyzed using both quantitative and qualitative methods. Based on the results, the average score of students' mathematical creative thinking across all questions was 80.81%, falling into the "very effective" category. The highest score was recorded on question number 2 with 86.50%, while the lowest was on question number 4 with 74.50%. The conclusion of this research is that the PBL-based E-Worksheet, supported by the Bangsidat application, is highly valid, practical, and effective in enhancing students' creative.

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Corresponding Author:

Upik Haryono,
Department of Mathematics Education,
Institut Keguruan dan Ilmu Pendidikan Siliwangi,
Jl. Terusan Jend. Sudirman, Cimahi, Indonesia
Email: upikharyono03061980@gmail.com

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INTRODUCTION

Mathematical creative thinking ability is a way of thinking that aims to analyze arguments and generate new ideas related to meaning and attitudes, in order to improve logical thinking patterns—something that educators should enhance during the learning process (Hutasuhut, 2019). Creative thinking is the ability to create new concepts or methods to produce something,

and generally, such thinking is driven by challenges or problems encountered (Umar & Abdullah, 2020). The significance of mathematical creative thinking lies in preparing students to think more complexly and analytically in facing mathematical challenges (Astria & Kusuma, 2023). The ability to think creatively is one of the essential skills that students, including those at the junior high school level, must possess in learning mathematics (Situmorang et al., 2023). Creative thinking is an activity that involves the ability to express or solve problems to create and produce new ideas based on prior understanding (Huliatunisa et al., 2020). According to previous research, mathematical creative thinking is a higher-order thinking skill that allows students to maintain a diversity of ideas or arguments in solving various mathematical problems. Therefore, creative thinking is crucial for students as it helps them understand, manage, and solve problems innovatively, while also fostering curiosity and adaptability in an ever-evolving world.

The lack of support to develop students' creative thinking skills has resulted in weak creative thinking abilities, which negatively impact learning outcomes (Aflah et al., 2023). One of the reasons behind the low levels of students' creative thinking is the widespread perception that mathematics is a difficult and intimidating subject (Satria et al., 2023). Previous studies have shown that the creative mathematical thinking skills of Indonesian students remain relatively low. Complex global problems and local challenges in Indonesia—such as the need for innovative curriculum development, effective learning evaluations, and improved teacher quality—can serve as motivators for fostering creative mathematical thinking to find innovative solutions. The issue addressed in this study is the low ability of students to answer a variety of questions creatively, where although their answers may vary, they often lack motivation to explore or develop problem-solving strategies further.

To address this issue, the researcher proposes the development of a student worksheet based on the Problem-Based Learning (PBL) model to foster students' creative thinking. PBL is considered suitable because creative thinking can develop effectively when the learning process is student-centered, allowing students to freely express ideas originating from themselves, in an environment that encourages active participation (Indayanti & Sagala, 2023). Problem-Based Learning positions students as independent learners who act as the main agents in the educational process, with the expectation that they will think creatively and develop innovations in learning mathematics (Maydilla Fadiarahma Vistara, Rasiman, Lukman Harun, 2023). In addition to using the PBL model to enhance students' mathematical creative thinking skills, the researcher also developed an Android-assisted Electronic Student Worksheet (E-Worksheet) as a tool to overcome deficiencies in creative thinking. The E-Worksheet is a digital learning medium that presents material in a more concise and structured format (Sari, 2023). It is designed to engage students more actively and creatively in understanding various topics by integrating multimedia features such as images, videos, and audio (Tiwi et al., 2023). As a digital teaching material, the E-Worksheet has the potential to attract students' attention and interest in learning, thus helping them summarize learning content more effectively through an Android-based format (Ayunda et al., 2023).

Previous studies on E-Worksheet include research by Siregar & Suparman (2022) on developing a PBL-based E-Worksheet to improve mathematical communication skills, and Fitria et al. (2023) who explored mathematical creative thinking based on self-esteem in the PBL model with a STEAM approach. Ani Oktafiani & Nindiasari (2023) developed a PBL-based E-Worksheet to enhance reflective mathematical thinking skills. These E-Worksheets, which focus on Higher Order Thinking Skills (HOTS) and PBL, are expected to develop students' advanced thinking abilities, particularly creative thinking (Renita & Rusdi, 2023). Field observations through interviews with mathematics teachers indicate that worksheets currently used are mostly paper-based, with some teachers not using worksheets at all. From

the aforementioned research, none has developed a PBL-based E-Worksheet supported by the Android application *Bangsdat* to enhance students' mathematical creative thinking skills. Therefore, the primary aim of this study is to develop an Android-based student worksheet to improve students' mathematical creative thinking ability.

METHOD

The method used in this research is Design Research (Development Studies). The aim of this study is to develop an Electronic Student Worksheet (E-Worksheet) using a problem-based learning approach supported by an Android application (*Bangsdat*). The research subjects were 28 eighth-grade students from SMP Negeri 2 Haurgeulis. Four students participated in individual trials (one-on-one testing), eight students were involved in small group trials, and all 28 students took part in the field trial. This study was conducted at SMP Negeri 2 Haurgeulis, Haurgeulis District, Indramayu Regency.

The data collection techniques used in this study included interviews, document analysis, and questionnaires in the form of attitude scales to validate the feasibility and practicality of the developed E-Worksheet. Additionally, test questions were used to measure the effectiveness of the developed E-Worksheet. The validation and practicality assessment techniques used the following formula:

$$P = \frac{S}{N} \times 100\%$$

P = Percentage,

S = Score obtained,

N = Maximum score.

The results obtained can be seen in table 1.

Table 1. Analysis of E-Worksheet validity and Usability.

Score	Criteria
0 – 20	Highly Invalid/Higly Imperical
21 – 40	Invalid/Impractical
41 – 60	Somewhat Valid/Shomewhat Practical
61 – 80	Valid/Usabel
81 – 100	Highly Valid/Highly Practical

The effectiveness of E-Worksheet, as seen from the students' mathematical creative thinking ability scores. The scores obtained by students in the posttest are used with the following formula:

$$P = \frac{S}{N} \times 100\%$$

P = Percentage

S = Score obtained

N = Maximum score

The results obtained can be seen in table 2.

Table 2. Interpretation of E-Worksheet effectiveness.

Score	Criteria
0 – 20	Very ineffective
21 – 40	Ineffective
41 – 60	Quite effective
61 – 80	Effective
81 – 100	Very effective

The steps taken by the researcher in this study are as follows:

1. Preliminary Stage

This stage is carried out to determine the research location, subjects, and set the research implementation schedule.

2. Formative Evaluation Stage

This phase is broken down into three components, specifically introspection, model creation, and practical assessment.

3. Self-Evaluation Stage

The investigator split the sub-stage into two parts: analysis and design. During the analysis phase, the investigator performed an evaluation of the students, the assignments, and the curriculum. The elements examined from the students included the traits related to their abilities in creative mathematical thinking.. The required student characteristics are students who are heterogeneous in mathematical creative thinking abilities and students' abilities in assigning basic mathematical concepts. This information was obtained from interviews with teachers and students. Based on this information, the researcher divided the students into three groups consisting of low, medium, and high.

Meanwhile, the aspects analyzed from the curriculum were core competencies, basic competencies of flat-sided solid geometry material to be elaborated into learning objectives that serve as guidelines for the preparation of E-Worksheet. In addition, the researcher also analyzed learning resources such as source books, teaching materials obtained through the internet about flat-sided solid geometry material. In the development phase, the investigator created a product that utilized problem-based learning through the Bangsidat Android application to enhance students' capabilities in mathematical creative thinking. The E-Worksheet framework concentrates on five key elements: (1) Subject matter; (2) delivery method; (3) wording; (4) alignment with problem-based learning strategy; and (5) correspondence with the fundamentals of E-Worksheet creation (refer to table 3) as detailed below:

Table 3. Characteristics of E-Worksheet Development

No.	Development Aspect	Indicator
1	Content Feasibility	- Relevance of Basic Concepts
		- Accuracy of E-Worksheet
		- Novelty in E-Worksheet
2	Presentation	- Application Display
		- Layout of Tools
		- Menu Suitability

No.	Development Aspect	Indicator
3	Language	<ul style="list-style-type: none"> - Communicative and Interactive - Suitability with Student Development Stage - Compliance with Indonesian Language Rules - Accuracy of Symbols and Use of Terms - Introducing Students to the Issue - Structuring Students Around the Challenge
4	Suitability with PBL Syntax	<ul style="list-style-type: none"> - Directing Research - Creating and Showcasing Findings - Examining and Assessing the Problem-Solving Approach
5	Suitability with E-Worksheet Development Principles	<ul style="list-style-type: none"> - Ease of Use - Accuracy in Application Selection - E-Worksheet is Simple

Prototype Design, This activity is divided into three sub-stages, namely expert review, individual trials, and small group trials. In these sub-stages, an evaluation of the designed product is carried out.

a. Expert Review

At this stage, practitioners considered experts in media or materials validate and evaluate the E-Worksheet designed in the self-evaluation stage (prototype I design), which functions to see the advantages and disadvantages of the E-Worksheet. These practitioners provide comments on the E-Worksheet development characteristics in table 1, which are then written in a validation sheet as a form of guidance in revising the E-Worksheet. Thus, based on expert comments, the researcher revises the E-Worksheet. The result of the prototype I improvement is called prototype II.

b. Individual Trials

This activity is carried out during expert review by conducting individual trials on four students with high, medium, and low ability categories. Using attitude scales and interviews in individual trials, the focus is on prototype I, which has been developed, regarding validity combined with experts. The results of this improvement are used to improve prototype I into prototype II.

c. Small Group Trials

Small group trials are conducted by eight students who are the subject samples for the small group. Student selection is based on suggestions from subject teachers by looking at their abilities (low, medium, and high). Meanwhile, interview data and attitude scales at the small group stage aim to obtain data for revising prototype II regarding the practicality of E-Worksheet, which will be analyzed descriptively. With input and suggestions from students in these trials, the E-Worksheet will be improved, resulting in prototype III.

d. Field Test

This trial is attended by more participants than the previous trials. This field trial is attended by 28 eighth-grade students of SMPN 2 Haurgeulis. The product being tested is a product that meets the validation criteria and quality according to experts, and practicality

according to student responses, which have been considered suitable for use in improving students' mathematical creative thinking abilities.

RESULTS AND DISCUSSIONS

In order to enhance comprehension and readability, the findings of the research are outlined initially, with the analysis following. Distinct subheadings for findings and analysis are provided separately. This segment is intended to be the most substantial portion, comprising at least 60% of the total article content.

Results

Preparation Stage

This research activity was carried out at SMP Negeri 2 Haurgeulis, Haurgeulis District, Indramayu Regency, on April 14–27, 2024. The research subjects were 28 seventh-grade students of SMP Negeri 2 Haurgeulis. Four people were selected to be subjects in individual trials, eight students were selected as subjects in small group trials, and 28 students were used as subjects in field trials.

Formative Evaluation Stage

The evaluation carried out at this stage consists of two development sub-stages: self-evaluation and prototype design.

Self-Evaluation

Based on the development characteristics (see table 3), the E-Worksheet design with PBL-based learning using the Android application Bangsidat, after the prototype design is made, is then reviewed based on the characteristics in table 3 and then validated by experienced peers, both in terms of content, design, and language used. From the E-Worksheet design, results will be obtained in the form of an E-Worksheet display using the Android application Bangsidat.

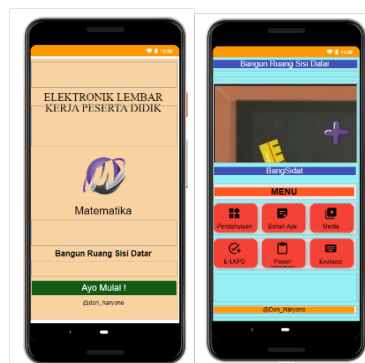


Figure 1. E-Worksheet Display Using the Android Bangsidat Application

Designing the Prototype

1. Expert Review

The E-Worksheet designed in prototype I will be evaluated and validated by experts, then the experts will provide recommendations for improving E-Worksheet prototype I. These recommendations are outlined in table 4.

Table 4. Expert Comments and Suggestions

No.	Suggestions and Comments	Repair
1	E-Worksheet needs to further improve the ease of use of the application	Improvement of the menu in the Bangsidat application
2	The learning scenario does not sufficiently foster mathematical creativity	Enhancing the Android Bangsidat app by refining and incorporating menus to boost students' creative thinking skills in mathematics.
3	The steps in the PBL approach are still not visible enough in the E-Worksheet	Completing the PBL syntax in the E-Worksheet Bangsidat application

Meanwhile, the validation results from the experts, consisting of two material experts and two application experts, are presented in table 5.

Table 5. Phase 1 Validation Results of E-Worksheets

No.	Observed Aspect	Validator		Average Percentage	Criteria
		1	2		
1	Content Feasibility	74%	75%	75%	Valid
2	Presentation	70%	74%	72%	Valid
3	Leanguae	76%	79%	78%	Valid
4	Suitability of PBL Syntax	73%	77%	75%	Valid
5	Suitability with E-Worksheet Development Principles	74%	74%	74%	Valid
Average percentage all aspects				74,80%	Valid

Based on table 5, the results of the first stage of validation obtained an average score of 74.80% with a "valid" category. It can be concluded that the E-Worksheet is suitable for use with a valid category of validity. Considering input from various reviewers, the researcher made improvements which were carried out in stage 2. The results of the second stage of validation are presented in table 6.

Table 6. Phase 2 Validation Results of E-Worksheets

No.	Aspects Observed	Validator		Pententation Average	Criteria
		1	2		
1	Content Feasibility	84%	85%	85%	Highly Valid
2	Presentation	84%	84%	84%	Highly Valid

No.	Aspects Observed	Validator		Persentation Average	Criteria
		1	2		
3	Leanguae	86%	89%	88%	Highly Valid
4	Suitability of PBL Syntax	89%	87%	88%	Highly Valid
5	Suitability with E-Worksheet Development Principles	90%	89%	90%	Highly Valid
Average percentage of all aspects				87%	Highly Valid

Based on Table 6, the results of the second stage of validation obtained a score of 87% with a 'highly valid' category. Thus, it can be concluded that the E-Worksheet is very suitable for use with a 'very valid' category of validity. Based on input and suggestions from reviewers, the researcher made several revisions, one example of which is presented in Figure 2.

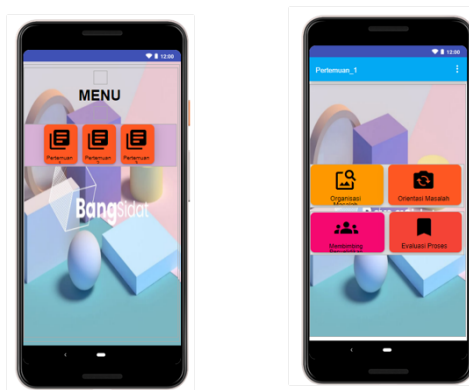


Figure 2. Example of Improvements on the Developed E-Worksheet

One-on-One Evaluation

After validation and evaluation from experts (expert review) of the developed E-Worksheet, the Bangsidat E-Worksheet application was given to 4 sixth-grade students of SDN 3 Bugis, Anjatan District, Indramayu Regency, through individual testing. Students then provided comments and suggestions about the developed E-Worksheet. Each student provided feedback on the practicality of the Bangsidat application, which included usefulness, ease, novelty, and attractiveness of the Bangsidat E-Worksheet application. The practicality results are presented in table 7.

Table 7. Practicality Test Results at the One-on-One Evaluation Stage

No.	Indicator	Percentage	Criteria
1	Usefulness	73%	Partical
2	Ease	75%	Partical
3	Novelty	77%	Partical
4	Attractiveness	75%	Partical

Average percentage of each indicator	75%	Partical
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According to the personal test findings in Table 7, the proportion of student feedback for the Bangsidat E-Worksheet application stood at 75%, placing it into the 'practical' classification. This suggests that the E-Worksheet is suitable for reevaluation in a smaller group assessment.

Small Group Test

This stage tested the practicality on a small group of 8 eighth-grade students of SMP Negeri 2 Haurgeulis. The practicality test results are shown in Table 8.

Table 8. Practicality test results in Small Group stage

No.	Indicator	Percentage	Criteria
1	Usefulness	78%	Partical
2	Ease	77%	Partical
3	Novelty	78%	Partical
4	Attractiveness	78%	Partical
Average percentage of each indicator		77,75%	Partical

Based on the Problem Based Learning-based E-Worksheet trial in the table above, the percentage score obtained was 77.75% with a 'practical' category, which means that the E-Worksheet can be developed through field testing.

Field Try Out

The concluding phase of the formative assessment involves field testing. Twenty-eight students from SMPN 2 Haurgeulis participated in this field test. The goal of the field test was to evaluate how effectively the problem-based learning-focused E-Worksheet, supported by the Bangsidat Android application, enhances students' abilities in mathematical creative thinking, as illustrated in Table 9.

Table 9. Effectiveness of E-Worksheet to improve students' mathematical creative thinking abilities

No.	Average	Category
Question 1	85,70%	Verry Effective
Question 2	86,50	Verry Effective
Question 3	76,55	Effective
Question 4	74,50	Effective
Average	80,81%	Verry Effective

The table above shows that students' mathematical creative thinking abilities for all questions obtained average score of 80.81% with a 'very effective' category. Question number 2 had the highest score of 86.50%, while question number 4 had the lowest score of 74.50%. In addition, the pretest and posttest results are presented in Figure 3 below.

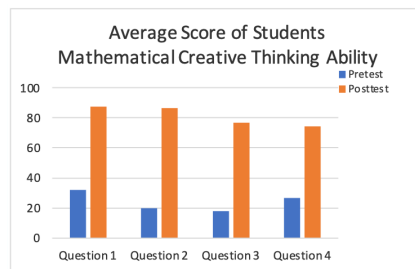


Figure 3. Student Pretest and Posttest Scores in Field Testing

Figure 3 shows that students' mathematical creative thinking ability scores in the posttest showed a significant increase compared to the pretest. This occurred because after the learning process using PBL-based E-Worksheet assisted by the Android Bangsidat application, students' mathematical creative thinking ability increased significantly. Problem-Based Learning-based E-Worksheet is valid, effective, and practical to use, and also enhances students' creative thinking abilities (Sari, 2023). Worksheet and E-Worksheet are work guides that help students learn. This E-Worksheet can be accessed on PCs, laptops, or smartphones (Oktavia & Musdi, 2023). Problem-Based Learning (PBL) is a student-centered learning model, where this model is based on problem-solving. This model teaches students to solve problems in finding concepts, principles, and training students to conduct investigations (Putri Fauziah Yazmin & Risda Amini, 2023). With the use of PBL-based E-Worksheet assisted by the Android Bangsidat application, students can improve their mathematical creative thinking abilities because the use of this application is very practical and easy to use.

Discussions

The results of this study show that the use of a Problem-Based Learning (PBL)-based E-Worksheet supported by the Bangsidat Android application is highly effective in improving students' mathematical creative thinking ability, with an average score of 80.81%, categorized as very effective. These findings align with and enrich previous research results. First, this result is consistent with the findings of Sari (2023), which stated that a PBL-based E-Worksheet can enhance students' creative thinking skills in Social Arithmetic material. Although the subject matter differs, the effectiveness of using PBL-based E-Worksheets remains consistent. Second, the findings are supported by Fitria et al. (2023), who examined mathematical creative thinking ability based on self-esteem in a PBL model with a STEAM approach. Their study demonstrated that integrating PBL into learning media encourages students to develop creative solutions in tackling mathematical problems. Third, this study also aligns with the findings of Siregar and Suparman (2022), who developed a PBL-based E-Worksheet to improve students' mathematical communication skills. Although the focus was on communication rather than creativity, both studies show that the PBL approach through E-Worksheets is effective in fostering higher-order thinking skills. Fourth, the results are comparable to Oktafiani & Nindiasari (2023), who developed a PBL-based E-Worksheet to enhance students' reflective mathematical thinking skills. Their research also showed a significant improvement in students' cognitive processes when solving problems, which is evident in this study through the substantial increase in posttest scores. Fifth, this research provides a more comprehensive contribution than previous studies such as Ayunda et al. (2023), who focused on developing an Android-based E-Worksheet using Kodular. While their study emphasized technical aspects of media development, this study adds a pedagogical dimension by implementing PBL and directly evaluating its effect on students' creative thinking ability. Therefore, these comparisons indicate that the PBL-based E-Worksheet supported by the Bangsidat Android application is not only valid and practical but also highly effective in enhancing students' mathematical

creative thinking. The integration of technology and problem-based approaches in learning has proven to be a relevant strategy for improving the quality of mathematics education in the digital era.

CONCLUSION

Based on the data processing and discussion conducted, it is concluded that the development of PBL-based E-Worksheet assisted by the Android Bangsidat application is declared valid, practical, and very effective in improving students' mathematical creative thinking abilities. Therefore, PBL-based E-Worksheet assisted by the Android Bangsidat application is suitable for use in the mathematics learning process of flat-sided solid geometry material.

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