Development of PBL-based E-Worksheet for 8th Grade Students' Critical Thinking Skills

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Abstract

This research developed e-worksheet based on Problem Based Learning (PBL) to improve the problem-solving abilities of grade VIII students. The development method uses the ADDIE model, with validation instruments, student responses, as well as pretest and posttest. The validation results show a high level of validity of the e-worksheet. Student responses to E-worksheet are also positive. Pretest and posttest analysis showed a significant increase in problem solving abilities. However, this increase is still limited due to time constraints.

Keywords: problem-solving, problem-based learning approach, number patterns

INTRODUCTION

The 21st century demands quality individuals with skills such as problem solving, communication, collaboration and creativity (Mardhiyah et al., 2021; Soepriyanto, 2018; Prihadi, 2018). In the context of mathematics learning, problem-solving skills are important (Son et al., 2020; National Council of Teachers of Mathematics, 2000). However, many students still experience difficulties in solving mathematical problems, especially in real contexts (Suryani et al., 2020; Yustianingsih et al., 2017). Research shows that many students face obstacles in converting problems into mathematical symbols, determining formulas, and writing down solution steps (Halim et al., 2021; Mariam et al., 2019; Rahayu, 2018; Suraji, 2018).

Students at Baitussalam Prambanan IT Middle School, class VIII, also experienced several common mistakes in solving problems, such as errors in collecting information, determining formulas, preparing structured solution steps, proving solution results, and concluding problem solving results. This is reinforced by the results of observations, interviews and pretests which show difficulties in number pattern material.

The pretest results show that the problem solving abilities of class VIII students at Junior High School IT Baitussalam Prambanan are still low, with the majority of students scoring below 59. This shows the need to improve problem solving abilities. Interviews with students revealed that learning mathematics was considered less interesting because it was monotonous, especially

Due to the lack of group activities and teaching materials that only contain practice questions without clear assignment instructions. Therefore, it is recommended that teachers develop teaching materials that are more interesting and lead to problem solving activities and provide clear assignment instructions to students. (Khulsum et al., 2018).
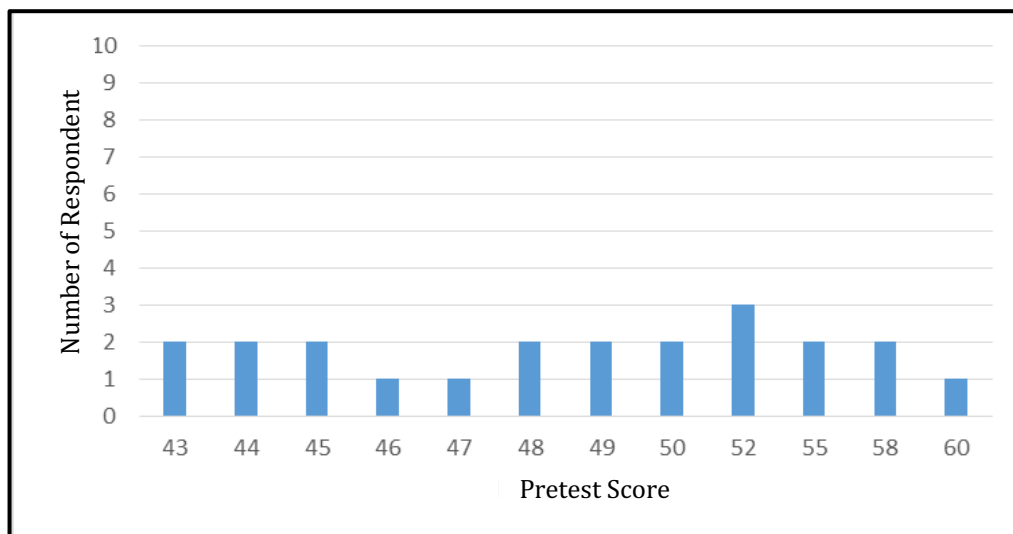
Figure 1. Pretest Result of Number Patterns

The results of the interviews were strengthened by a questionnaire about teaching materials that students liked. Students can choose whatever teaching materials they like and want to try in learning mathematics.
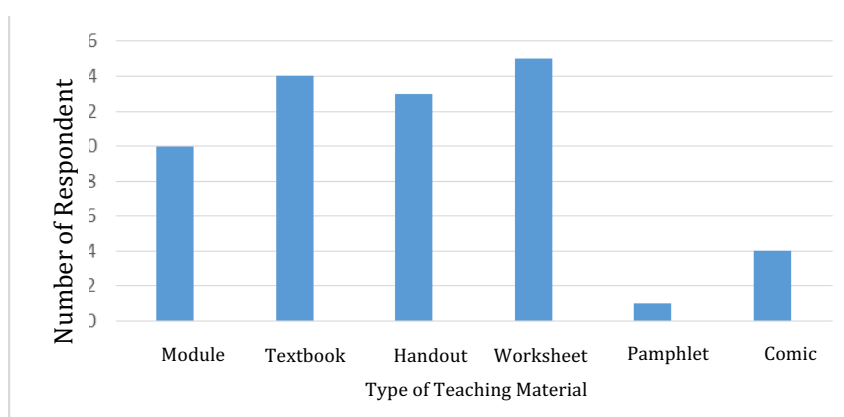

Figure 2. Instructional Material Needs Analysis

The picture above shows students' preferences for various types of teaching materials, with worksheet being the largest choice (26%). These results are in accordance with students' desires for more interesting learning, equipped with assignments and group activities, as expressed in interviews. Worksheet is known to be effective in encouraging student activities and can be used digitally, such as E-worksheet, which attracts students' interest and motivation (Apriliyani & Mulyatna, 2021). Apart from that, worksheet that uses a Problem Based Learning approach can improve students' mathematical problem solving abilities (Yustianingsih, 2017). This approach encourages students to participate actively in solving contextual problems, which is in accordance with the characteristics of class VIII students at Junior High School IT Baitussalam who require learning that is more oriented towards problem solving (Agitsna et al., 2019). Therefore, developing teaching materials based on a problem-based learning approach that is oriented towards problem-solving abilities is important in improving students' problem-solving abilities in mathematics learning, especially for number pattern material.

RESEARCH METHOD

This research uses the Research and Development (R&D) method which aims to produce valid research products through a cyclic and repetitive process, such as field testing and product revisions (Wardoyo, 2019; Borg and Gall, 2003). The research model used is the ADDIE model, which consists of analysis, design, development, implementation and evaluation stages (Branch, 2009). The ADDIE model was chosen because it supports the development of multimedia-based learning, in line with research by Tanjung and Parsika (2014) which shows that the ADDIE approach is widely used for developing CBT applications or multimedia-based learning.

The research procedure follows the ADDIE model which consists of the Analysis, Design, Development, Implementation and Evaluation stages (Branch, 2009). The Analysis stage involves analysis of student needs, curriculum analysis, and analysis of learning conditions in mathematics classes. The Design stage includes product planning based on the analysis results, including instrument design and validator determination. The Development stage involves developing E- worksheet using FaPa FlipBook Extender by compiling content and interactive elements. The Implementation stage involves testing the product on students, by providing response questionnaires, pretests and posttests. The Evaluation stage is an assessment of the validity, practicality and effectiveness of the product, and improvements are made based on the evaluation results (Branch, 2009).

This research involves two types of validators: instrument validators and product validators. The instrument validator is Dr. Andriyani, M.Si, while the product validators consist of material experts and media experts. Material experts consist of Dr. Andriyani, M.Si, Dr. Puguh Prasetyo, S.Si., M.Sc, and Nuzulia Rahma, S.Pd., while media experts consist of Dr. Puguh Prasetyo, S.Si., M.Sc, Dr. Burhanudin Arif Nurnugroho, M.Sc, and Fajri Nur Hidayati, S.Pd. The research subjects consisted of class VIII students at Junior High School IT Baitussalam Prambanan, with 22 students randomly selected as samples to use E- worksheet. Data collection techniques involve observations of the curriculum, lesson plans and teaching materials, interviews with teachers and students, validation questionnaires, student assessment questionnaires, and pretest-posttest test questions. Data collection instruments consist of validation sheets, student assessment sheets, and pretest-posttest test instruments. (Branch, 2009).

To evaluate the validity of the E- worksheet by material experts, two analysis techniques were carried out. First, using the average validation score with the formula from Larson and Farber (2012). The second technique is to determine the interval distance using the formula from Widoyoko (2018). Based on the results of the analysis, the validity categories of E- worksheet by material experts are divided into five, namely very valid, valid, quite valid, less valid and invalid.

Furthermore, the validity of the E- worksheet by media experts was also evaluated using the same two analysis techniques. The results are also divided into five validity categories which are the same as validity by material experts.

To evaluate the practicality of students' responses, two similar analysis techniques were also used. The results were categorized into five, from very practical to impractical.

All analysis results are then presented in appropriate tables, showing the validity and practicality categories of each evaluation aspect. (Larson & Farber, 2012; Widoyoko, 2018).

Validity Evaluation by Material and Media Experts:

$$R_v = \frac{\sum_{i=1}^{n} V_i}{n}$$

Note:
R_v : Average Validation Score
V_i : Total validation score for each validator, $i = 1,2,3,\ldots,n$
$n.$: Number of validator

Interval Distance for material and media experts:

$$J_i = \frac{S_{max} - S_{min}}{\sum K_i}$$

Note:
J_i : Interval distance
$Smax$: Ideal maximum score
$Smin$: Ideal minimum score
$\sum Ki$: Many Interval Classes of i = 5

The effectiveness of E- worksheet is assessed based on the increase in posttest scores compared to the pretest scores. Students' problem-solving abilities are analyzed through pretest and posttest results.

Steps to analyze the effectiveness of E- worksheet: Test the normality of pretest and posttest data to determine data distribution, If the data is normally distributed (Sig. value > 0.05), carry out a paired sample t-test, Use the results of the paired sample t-test to determine the significance of the difference between the average pretest and posttest scores, If the Sig value. > 0.05, then accept the null hypothesis (H0), meaning there is no significant difference between the pretest and posttest scores, If H0 is rejected, it means there is a significant difference between the pretest and posttest scores. The significant difference shows the effectiveness of E- worksheet in improving students' problem-solving abilities.

RESULTS AND DISCUSSION
The development of number pattern E- worksheet uses the ADDIE approach, which consists of analysis, design, development, implementation and evaluation stages. The analysis stage includes analysis of student needs and curriculum. The design stage includes product and instrument planning in accordance with the analysis results. Development was carried out using the FaPa FlipBook Extender. The implementation phase involves trials with students, with response assessments and tests. The evaluation stage is carried out to evaluate the validity, practicality and effectiveness of the product.

The analysis stage of developing E- worksheet number patterns for class VIII junior high school students at Junior High School IT Baitussalam Prambanan includes curriculum analysis, conditions and situations, as well as student characteristics. The curriculum used has been adapted to the 2013 Revised 2017 Curriculum and is based on the Problem Based Learning approach. The number pattern material is in accordance with the Core Competencies (KI) and Basic Competencies (KD) in the curriculum. Observations show that the current use of teaching materials is less varied and does not support problem solving, so new teaching materials are needed that are oriented

towards problem solving abilities. Analysis of the characteristics of students shows that they prefer worksheet as teaching materials, and have difficulties, especially in finding information, formulating problems, and solving problems. Based on the results of this analysis, the development of E- worksheet based on Problem Based Learning and oriented towards problem solving abilities is considered necessary to improve the quality of learning. Source: E- worksheet Development Analysis Document for Junior High School IT Baitussalam Prambanan.

Table 1. Basic Competencies and Competency Achievement Index

Basic Competencies (KD)	Competency Achievement Indicators (GPA)
1. Make generalizations of patterns in number sequences and object configuration sequences	1. Students can determine various number patterns 2. Students can calculate number sequences and object configuration sequences 3. Students can infer patterns in number sequences and object configuration sequences
1. Solving problems related to patterns in number sequences and object configuration sequences	1. Students can solve problems related to patterns in number sequences and object configuration sequences 2. Students can present the results of solving pattern problems in number sequences and object configuration sequences

At the design stage, the steps taken by the researcher were: (1). Determine the design components of the teaching materials being developed, especially for number pattern material. (2) Breaking number pattern material into two components, namely Basic Competency (KD) knowledge and KD skills. (3). Basic Competencies (KD) are then translated into Competency Achievement Indicators (GPA). (4). The GPA is then reduced to a learning objective.

Table 2. Symbols of the stages of the Problem Based Learning approach

Symbol	*Problem based learning* syntax
	Problem orientation
	Organizing to learn
	Guiding the investigation
	Develop and present work results
	Analyze and evaluate the problem-solving process

Researchers complete the E- worksheet with number pattern material with indicators of problem-solving abilities, including searching for and identifying known elements, formulating problems or mathematical approaches, explaining results

according to appropriate solving strategies, and using mathematics meaningfully. This helps students develop effective problem-solving abilities.

Table 3. Symbols of the indicators of the problem-solving

Symbol	Problem-solving indicator
	Identify known elements
	Formulate a problem or mathematical approach
	Implement strategies to solve problems
	Explain the results according to the problem-solving strategy
	Use mathematics meaningfully

Researchers designed E- worksheet based on Problem Based Learning with a focus on problem solving abilities. The learning objectives of E- worksheet are related to increasing problem solving abilities, with activities according to predetermined indicators. Learning objectives include the ability to determine various number patterns, calculate number sequences, infer patterns in number sequences, and solve related contextual problems.

The E- worksheet cover is designed with a striking mathematical title, followed by the title "Number Patterns" to clarify the content. Apart from that, it is stated that this E- worksheet is based on Problem Based Learning and is oriented towards problem solving abilities to show its approach and focus.

Table 4. Feedback from validator Dr. Andriyani, M.Si.

Validator	Feedback and suggestions	Information
Dr. Andriyani, M.Si.	Adapt to PUBEI and fix typos as in the instrument reviewed	Suitable for use after revision

The media expert validation instrument was validated by a master lecturer in Mathematics Education at Ahmad Dahlan University. The results of the assessment by the validator are presented in Table 5.

Table 5. Validation results by the validator

Validator	Feedback and suggestions	Information
Dr. Andriyani, M.Si.	Correct typos according to suggestions in the instrument that has been reviewed	Suitable for use after revision

The student response questionnaire instrument has been validated by an expert, a master lecturer in mathematics education, on May 20 2023. The validation results show that the instrument is suitable for use as a student response questionnaire. Expert input and suggestions on the instrument review sheet can be seen in the table.

Table 6. Expert feedback and suggestions on the instrument review sheet

Validator	Feedback and suggestions	Information
Dr. Andriyani, M.Si.	Several aspect points in students' responses need to be adjusted to indicators of problem-solving abilities	Suitable for use after revision

The pretest and posttest question instruments have been validated by an expert, a master's lecturer in mathematics education, on April 29 2023. Based on problem solving indicators, the instrument was prepared with a focus on students' ability to search for information, prepare problem solving plans, implement problem solving plans , and check the correctness of the problem solving results. Input and suggestions from validators regarding the instrument can be seen in the table.

Table 7. Feedback and suggestions from the validator regarding the instrument

Validator	Feedback and suggestions	Information
Dr. Andriyani, M.Si.	Adjust the questions with problem solving indicators	Suitable for use after revision

Researchers carried out the validation stage of the E- worksheet by media experts, including two lecturers from Ahmad Dahlan University and one mathematics teacher from SMP N 3 Banguntapan. Dr. Puguh Prasetyo, S.Si., M.Sc stated that E- worksheet is suitable for use without revision. Dr. Burhanudin Arif Nurnugroho, M.Sc provided input to make the illustration on the cover closer to the E- worksheet material, correcting empty spaces, correcting errors in writing, and using equations in writing mathematical notation. Fajri Nur Hidayati, S.Pd. gave feedback that the video only conveyed the questions in the assignment without explaining the material, and that the background music was too loud so that the narrative voice could not be heard.

After revision, the E- worksheet cover was adapted to the number pattern material by adding a picture of the arrangement of coins. Empty space on E- worksheet repaired. Changes to the image and writing layout were made to tidy up the writing and remove the billiard ball numbers in the image.

The media expert validation results show that validator 1's score is 129 in the very valid category, validator 2's score is 112 in the valid category, and validator 3's score is 115 in the valid category. The average score of the three validators is 119 in the very valid category.

The implementation stage is carried out on a small scale and a large scale. On a small scale, the trial was carried out with 4 students, while on a large scale it was carried out with 22 class VIII students at Junior High School IT Baitussalam Prambanan. Implementation is carried out by downloading the E- worksheet, explaining its use, working on assignments, discussing assignments, and working on posttest questions. The implementation stage is carried out online and offline with the permission of the school principal.

This research develops E- worksheet (Electronic Student Worksheet) based on Problem Based Learning and oriented towards problem solving abilities for number pattern material. The E-Worksheet went through a validation stage by media and material experts as well as an implementation stage in the classroom. The evaluation

stage is carried out by giving pretests and posttests to students to measure their effectiveness.

The evaluation results show that the E- worksheet meets the criteria of being valid, practical and effective. Assessment by media and material experts resulted in a very valid and valid category, while student responses showed that E- worksheet was considered practical. Apart from that, there was a significant increase between the pretest and posttest scores, indicating the effectiveness of E- worksheet in improving students' problem-solving abilities.

CONCLUSION

Based on the research results, it can be concluded that the development of E- worksheet based on Problem Based Learning and oriented towards problem solving abilities through the ADDIE model meets the criteria of being very valid, practical and effective. This is evident from the validation of material and media experts, positive responses from students, as well as a significant increase in pretest and posttest results. Suggestions for further research are to pay attention to time constraints and student adaptation to using E- worksheet, as well as developing applications so that they can be used not only on smartphones.

DECLARATION
Author Contribution

All authors contribute in the research process, such as collecting the data, analyzing the data, and writing the manuscript. All authors approved the final manuscript.

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Conflict of Interest

Both authors declare that they have no competing interests.

Ethics Declaration

We as authors acknowledge that this work has been written based on ethical research that conforms with the regulations of our institutions and that we have obtained the permission from the relevant institutes when collecting data. We support the International Journal on Emerging Mathematics Education (IJEME) in maintaining high standards of personal conduct, practicing honesty in all our professional practices and endeavors.

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