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Learning Linear Equation in Two Variables Using PBL-based E-worksheets for Grade VIII

Firmawati, Puguh Wahyu Prasetyo*
Universitas Ahmad Dahlan, Jl. Pramuka No.42, Pandeyan, Kec. Umbulharjo, Kota Yogyakarta, Daerah Istimewa Yogyakarta 55161 Indonesia
e-mail: puguh.prasetyo@pmat.uad.ac.id

Abstract

One of the mathematics learning materials in class VIII, namely the system of linear equations in two variables, does not meet learning standards. One of the causes of students' critical thinking skills not being optimal is the lack of students' desire to ask questions. From the results of the pretest given by researchers to students, it appears that there are several errors in the system of linear equations in two variables equation material, namely that students are not able to model problems in mathematical form, students are also less capable. cannot fully apply the system of linear equations in two variables method. This research aims to develop an e-worksheet based on Problem Based Learning (PBL) to enhance students' critical thinking skills. Based on the validity test, e- worksheet with a valid PBL model is used for learning with an average material score of 4.53 and an average media score of 3.808. E-worksheets with the PBL model are said to be practical to use in the learning process based on an average student response of 4.134.

Keywords: critical thinking skills, e-worksheet, PBL, linear equation in two variables

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INTRODUCTION

In the 21st century, we have entered the era of Industrial Revolution 4.0 which has an impact on various aspects of life, including education (Hairun & Suparman, 2020). In the midst of these changes, critical thinking has become an important skill that students must have because of its social, scientific and functional relevance in the industrial revolution and developments of the 21st century (Miharja et al., 2019; Basri, 2019). Critical thinking skills as stated by Kusumaningrum and Suparman (2020) are the main focus in education, and their depiction varies depending on the learning context (Nygren et al., 2019).

Talking about critical thinking skills, we mean life skills that enable individuals to convey arguments clearly, ask the right questions, solve problems, and analyze and evaluate information (Saputra et al., 2020; Harjo et al., 2019). For a student, this ability is reflected in his ability to adapt his personal experience to new situations (Fernanda et al., 2019). This process, which is part of critical thinking, involves cognitive and affective aspects that enable effective problem solving (Gunur et al., 2019; Yasin et al., 2019; Mahanal et al., 2019).

In learning mathematics, where problem solving skills are very important, students are faced with the challenge of thinking clearly and communicating their ideas appropriately (Gunur et al., 2019; Umar et al., 2020). However, research shows that students' critical thinking abilities in Indonesia are still not satisfactory, especially at the secondary level (Fernanda et al., 2019; Sayekti & Suparman, 2020). The findings of

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the 2018 PISA Program show that Indonesia's position in mathematics ability is ranked 7th with a score of 379, far below the international average score (Fernanda et al., 2019).

One of the approaches proposed to improve critical thinking skills in learning is to apply the Problem Based Learning (PBL) model (Syafina & Suparman, 2019; Fitri et al., 2020). This model allows students to discover and solve real world problems, which in turn can improve their critical thinking abilities (Gunur et al., 2019). In the system of linear equations in two variables learning context, PBL can be an effective approach to help students understand concepts and develop their critical thinking skills (Sumarmin & Basri, 2020).

However, the application of PBL in learning still faces several obstacles, including the availability of appropriate learning resources. Existing teaching materials do not fully integrate critical thinking skills in learning (Gunur et al., 2019). A more innovative approach is needed in designing learning materials, one of which is by developing electronic student worksheets (e- worksheet) oriented towards PBL and critical thinking skills (Kusumaningrum & Suparman, 2020).

This research aims to develop e- worksheet with a PBL model that is oriented towards the critical thinking abilities of class VIII students. Through this development, it is hoped that learning tools can be created that will enable students to hone their critical thinking skills in a mathematical context, especially in solving system of linear equations in two variables problems. The steps for developing this e- worksheet include design, validation and practical testing of the device.

Thus, it is hoped that this research can contribute to improving the quality of mathematics learning at junior high school level, especially in developing students' critical thinking skills.

RESEARCH METHOD

This research focuses on testing the practicality and development of electronic student worksheets (e- worksheet) using the Problem Based Learning (PBL) model which is oriented towards students' critical thinking abilities. The research method used is Research and Development (R&D), with the aim of producing products in the form of PBL-based e- worksheet. Research subjects included validators, middle school/MTs mathematics teachers, class VIII students at Junior High School State 15 North Kabaena. Evaluation of e- worksheet is carried out through a questionnaire which includes assessing quality specifications and receiving suggestions and criticism by pre-trial validators at schools. Middle School/MTs mathematics teachers were involved in the process of implementing e- worksheet during the research. Interviews with teachers were also conducted to gain views on school conditions and students. Class VIII students of Junior High School State 15 North Kabaena were actively involved in testing the practicality and effectiveness of products in improving their critical thinking skills. The ADDIE development model was chosen as a framework because of its effectiveness in facilitating the construction of knowledge and skills in structured learning and teaching (Brunch, 2009). This model has also proven useful in addressing gaps in students' knowledge and skills. According to Brunch (2009), the ADDIE model is a generative process that applies concepts and theories in a particular learning context.

In designing the development of the ADDIE model there are five stages, including: Analysis, Design, Development, Implementation and Evaluation, but researchers only reached the implementation stage. In this research, the product that researchers will develop is an e- worksheet system of linear equations in two variables with a Problem

Based Learning model that is oriented towards students' critical thinking with stages implemented using the ADDIE model.

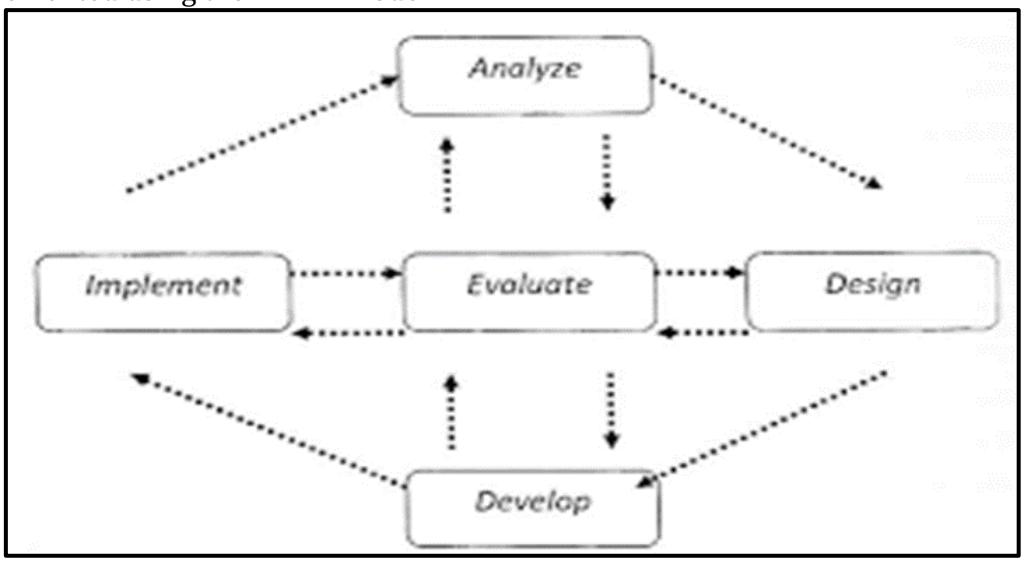

Figure 1. ADDIE Model Development Design

Source: Made & I Kirna Made. (2013).

This research aims to develop e- worksheet with the Problem Based Learning model. The following is a summary of the research procedures along with the stages of designing the ADDIE development model. Curriculum analysis and student characteristics, as well as material selection based on critical thinking skills. Design, develop learning program steps using the PBL approach. Apart from that, developing an e- worksheet -based learning media framework. Development of PBL e- worksheet with activities in the form of concept preparation, assessment instruments, student questionnaires, validation, revision and testing. Application of the product to students to evaluate practicality with data from student response questionnaires. In data collection, non-test (pretest) and test techniques were used. Data collection instruments include validation, student response questionnaires, and critical thinking ability tests.

This research tested instruments, including non-test and test instruments, to measure students' initial critical thinking abilities. The validity of test instruments must meet the criteria for construct validity and content validity, while non-test instruments are tested for construct validity through expert opinion. Test instruments are arranged based on learning objectives. After that, testing was carried out on the readability of the instrument. Data was changed from quantitative to qualitative to evaluate the validity and practicality of student worksheets. Qualitative data analysis is carried out to draw conclusions that can be understood by researchers and other people.

Data analysis refers to the interactive analysis of Miles and Huberman (2014) with the following stages: (1) Data reduction: at this stage the researcher summarizes the main and important things from the results of interviews and observations, and eliminates things that are not relevant to the research; (2) Data presentation (data display) is presented in various forms such as brief descriptions, tables, graphs, etc., to facilitate understanding; (3) Conclusion drawing (verification) is carried out to draw conclusions whether the e- worksheet being developed meets the valid and practical

criteria. Data analysis is used to obtain e- worksheet qualifications that meet these criteria.

The following is an explanation of these criteria validity analysis of e- worksheet. Validity analysis aims to obtain valid qualifications from the learning tools developed. The steps for processing data from validation results from material experts and media experts include tabulation and giving a score to each statement in the table. The average value is calculated using the appropriate formula. In determining the average value, the following formula is used.

$$\bar{X} = \frac{\sum_{i=1}^{n} X_i}{n}$$

Information:

$\overline{X}$ = Average score of e- worksheet assessment by Validator

X_i = score of indicator statement i, where i = 1, 2, 3, ..., n

n = Number of assessment items

Clarifying the results of the assessment provided by media experts and material experts. The assessment results are calculated by referring to Widoyoko (2018) and then classified to obtain a validity value. To get the validity value with the classification in table 5 below.

Based on the validity classification in the following table, calculations were carried out for material expert validators and media expert validators using the Likret scale as follows.

1. Highest = 5
2. Lowest = 1
3. Ideal Average = $\bar{X}_i = \frac{1}{2} \times (5 + 1) = 3$
4. Ideal standard deviation = $\frac{1}{6} \times (5 - 1) = 0.67$

From these calculations, the categorization of validation results by material expert validators and media expert validators is obtained as follows.

Table 1. Classification of Validity Criteria

No	Score	Category
1	$X > 4.206$	Excellent
2	$3{,}402 < X 4{,}206$	Good
3	$2.5998 < X 3.402$	Fair
4	$1{,}794 < X 2{,}598$	Poor
5	$X \leq 1.794$	Very Poor

Based on table 6 above, e- worksheet is said to be valid if the average score for the validity assessment meets the minimum criteria of "Good".

Minimum completeness criteria for critical and classical thinking are a reference for assessment determined by the education unit through subject teacher deliberations (MGMP) (Dirjen Dikmen, 2017). Minimum completeness criteria are made referring to graduation competency standards (SKL) by taking into account 3 (three) aspects, namely material complexity/competency, acceptance (quality of students), and supporting capacity of the educational unit. The following is an explanation of these 3 (three) aspects.

Aspects of material complexity/competency pays attention to the complexity of basic competence based on empirical data from the experience of teachers in the past. The higher the complexity of the material/competency aspect, the greater the challenge for teachers to improve their competence. Aspects of student intake pays attention to the quality of students which can be determined based on, among other things: school exam results at the previous level of education, previous report card scores, or the results of initial tests conducted by the education unit. The last aspect is carrying capacity aspect. Supporting capacity aspects means teacher availability, suitability of teacher educational background with the subjects taught, teacher competency (teacher competency test results), ratio of number of students in one class, learning infrastructure, financial support, and educational unit policies. The higher the teacher aspect and supporting capacity, the higher the minimum completeness criteria value. To facilitate the analysis of each basic competence, it is necessary to create an assessment scale agreed upon by the subject teacher as in the following table.

Table 2. Minimum Completeness Criteria and Assessment Scale

Aspects analyzed	Criteria and Rating Scale		
Material complexity of systems of linear equations in two variables	Tall <60	Currently 65 - 79	Low 800 - 100
Student intake in thinking	Low 80 - 100	Currently 65 - 79	Low <65
Carrying capacity	Tall 8 - 100	Currently 65 - 79	Low <65

The formula for determining minimum completeness criteria is as follows:

minimum completeness criteria = $\frac{Total\ score\ for\ each\ aspect}{3}$

RESULTS AND DISCUSSION

The results of this research present an e-worksheet based on PBL model focuses on critical thinking skills in class VIII. The research stages include analysis, design, development, implementation and evaluation stage.

Analysis Stage

The development of e-worksheet products with a Problem Based learning model in mathematics subjects with system of linear equations in two variables material is designed in accordance with the ADDIE model. The results of the analysis are described as follows.

System of linear equations in two variables material curriculum analysis. The results of interviews with mathematics teachers show that learning at Junior High School State 15 North Kabaena refers to the revised 2013 curriculum. However, even though the material has been directed according to the Core Competencies (KI) and Basic Competencies (KD) in the curriculum, it was found that students still experienced difficulties in several aspects.

Based on the situation and condition analysis, through direct observation of the learning process, it is known that the teaching methods used are still conventional. The

lack of presenting problems that encourage in-depth investigation and the lack of opportunities for students to communicate and present solutions to their problems are problems faced in mathematics learning.

The use of teaching materials in the form of Ministry of Education and Culture textbooks which tend to present material textually with formal mathematical symbolic language is also an obstacle. Apart from that, the integration of interactive technology in learning has not been implemented even though students and teachers are familiar with the use of smartphones.

Analysis of learner characteristics through interviews and initial tests it was discovered that students had difficulty giving logical reasons in solving problems. The results of the initial critical thinking skills test show that students are not yet able to use relevant information to solve problems and draw appropriate conclusions. They are also unable to explain in detail the basis for decision making and are less able to double-check the results of problem solving.

From this analysis it can be concluded that it is necessary to develop learning methods that are more interactive and oriented towards developing students' critical thinking skills, especially in the context of system of linear equations in two variables problem solving. Descriptively, the results of the critical thinking ability pretest which was carried out on Thursday, 20 October 2022 for class VIII students is presented in the Table 3.

Table 3. Pretest System of Linear Equations in Two Variables Critical Thinking Skills

Critical thinking indicators	Average Ideal Score	Average Achievement Score	Students' Percentage
Focus	3	2.21	73.61 %
Reason	2	0.54	18.06 %
Conclusion	2	0.88	29.17 %
Situation	3	1.21	40.28 %
Explain	2	0.71	23.61 %
Summary	2	0.75	25.00 %

Based on table above, it is known that the average achievement of students' critical thinking skills indicators is still relatively low because almost all critical thinking indicators are still below the ideal average except for the focus indicator. The five critical thinking indicators (reason, inference, situation, clarification, overview) have an achievement percentage of less than 60%, while the focus indicator has reached more than 60%. Equivalent to this achievement percentage, the average achievement score for the five critical thinking ability indicators (reasoning, inference, situation, clarification, overview) still appears to be below. From this it can be concluded that ideal average score of the critical thinking abilities of class VIII students at Junior High School State 15 North Kabaena are still low, with achievement of only one indicator out of six indicators. Therefore, in this research, researchers developed e- worksheet with a Problem Based Learning model to improve students' critical thinking skills in system of linear equations in two variables.

Design Stage

In this stage, the researcher carried out several activities. Designing teaching material components, the e- worksheet developed from the results of the analysis that has been

carried out contains system of linear equations in two variables material for class VIII and contains problem-based learning syntax with indicators of critical thinking skills. The design is carried out using a frame of reference which is focused on selecting material that is appropriate to the characteristics of students, competency demands, strategies or learning models applied, evaluations used, and increasing abilities.

Table 4. Syntax of PBL on the Material

Sintaks Problem Based Learning	Simbol
Identifying problem to the students	
Organizing the students to learn	
Supporting groups or individuals to investigate the problem	
Developing and presenting the results of the data	
Analyzing and evaluating the data	

E- worksheet is designed to see the practicality of e- worksheet which is oriented towards students' critical thinking skills. Students' critical thinking abilities are seen from the achievement of critical thinking indicators, namely focus, reasoning, inference, situation, clarification and overview. These symbols are placed on the e- worksheet page which indicates that the material on that page contains indicators of critical thinking.

Development Stage

At this stage, e- worksheet is developed according to the previous design. For the first time, an e- worksheet was designed using Canva and saved in PDF form. Next, the PDF is entered into the FaPa Flipbook PDF Corporate Edition application. Researchers also use videos from YouTube as interactive teaching materials. Additional features are needed that support this e-worksheet. Researchers used the FaPa book extender application to expand the Flip PDF Corporate Edition function on Android devices. The results are outlined in a configuration book that is tailored to the needs of the e-worksheet being developed. The next stage is consultation with material experts and media experts to develop the initial product into an e- worksheet product that is suitable for use in learning. The results of product validation and revision are described as follows.

First of all, the instrument that is validated (reviewed) is the test instrument, namely the instrument for the pretest. Validation (review) of the test instruments was carried out by one of the experts, namely academics from Ahmad Dahlan University, Yogyakarta. Validation is carried out to determine the suitability of the instrument based on content, construct and language. The results of the pretest instrument review can be seen in the Table 5.

Table 5. Pretest Instrument Learning Results

Validator	Suggestions and Feedback	Information
Expert 1	Instructions on reasoning/problem solving need to be presented in more communicative language so as not to give rise to multiple interpretations for students.	Worth using with revisions

Validation of e-worksheet material with the Problem Based Learning model developed was carried out by two material experts. The purpose of validating this material is to measure the accuracy and quality of the material presented on the e-worksheet with the Problem Based Learning model, namely on the subject of system of linear equations in two variables and to obtain the validity of the e- worksheet product with the Problem Based Learning model. developed. In general, the material expert assessment questionnaire consists of 5 (five) aspects, namely aspects of feasibility, content, language, suitability of presentation, Problem Based Learning model and indicators of critical thinking abilities.

The first material validation was provided by academics from Ahmad Dahlan University, Yogyakarta. The second material validation was provided by the mathematics subject teacher at Junior High School State 15 North Kabaena. This second material expert uses an e- worksheet product with a Problem Based Learning model who is accompanied directly by the researcher, so that the material expert can ask questions directly related to the e- worksheet product with a Question model.

CONCLUSION

Based on the results of research and development, the conclusions obtained from developing e- worksheet products using the Problem Based Learning model are as follows. The development of e- worksheet using the Problem Based Learning model is carried out using the ADDIE model through the following procedural stages: 1) analyzing the curriculum and materials according to the revised 2013 curriculum, analyzing learning conditions and situations that still require learning approaches and teaching materials that are appropriate to the characteristics of students; 2) designing e- worksheet and compiling various instruments, developing designs into prototypes and validating product prototypes; 3) apply the product to determine the practicality of the product

Testing the validity of e- worksheet products using the Problem Based Learning model can be seen from the results of material expert validation which produced an average score of 4.53 in the good category and the results of media expert validation which produced an average score of 3.808 in the good category. good category. The results of this assessment show that the e- worksheet with the Problem Based Learning model is overall valid in terms of suitability of content, language, suitability of presentation, syntactic content of problem-based learning, content of critical thinking indicators, suitable for use in the mathematics learning process.

The results of the practicality test in the small group showed an average score of 3.964 in the good category. The results of practicality tests in real classes show an average score of 4.134 in the good category. This shows overall that the e- worksheet with the Problem Based Learning model is seen from the aspects of interest, material and practical language used in the mathematics learning process.

Suggestions based on research and development are as follows. For students, technology can be used to learn flexibly through e- worksheet, allowing access anytime and anywhere. Students need to pay attention to their study time to maintain eye health. For teachers, Teachers are advised to provide alternative discussion of problems and step-by-step explanations to increase students' understanding. e- worksheet can be an alternative teaching material that is easy to use without requiring an internet connection. For schools, Schools need to support the development and use of teaching materials, including by holding training in making e- worksheet for teachers. This can improve student learning outcomes independently. For other developers, Further research is needed with a wider sample for the implementation stage. Apart from that, developing e- worksheet products must pay attention to covering all the basic things competencies and other mathematical material. Not only that, applications also need to be developed so that they can be accessed by students who use operating systems other than Android.

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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