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Development of Problem-Based Learning (PBL) Oriented E-Module to Improve Critical Thinking Skills for Elementary School Students

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Abstract: The purpose of this study is to analyze the development procedure, validity and effectiveness of PBL-oriented e-module to improve critical thinking skills in fractional calculation operation materials for grade V elementary school students. The type of research method carried out is research and development (R&D) with its development procedure, namely ADDIE, and data collection techniques in the form of teacher and student observation sheets, questionnaires for the validation of material experts, media and learning, teacher and student response questionnaires, and knowledge tests. The results of this study are: (1) the procedure for developing PBL-oriented e-modules using the ADDIE stage, (2) the results of the assessment by material, media and learning experts stated that PBL-oriented e-modules are in the category of Good or Suitable for use with an average percentage of 77.7%, (3) PBL-oriented e-modules are effective in improving the critical thinking skills of grade V elementary school students. It can be seen from the average score of students' critical thinking skills between pretest and posttest as well as the experimental group with the control group according to the target, there is a significant difference (0.000 < 0.05

Keywords: critical thinking skills; e-module**;** pbl.

INTRODUCTION

Mathematics learning in elementary school (Primary School) is not only abstract about numbers and logic of thinking, but will be more meaningful if it is contextual so that it becomes more concrete and of course is expected to be able to improve students' critical thinking skills. In addition, student-centered mathematics learning will be better able to improve students' learning motivation and critical thinking skills (Fajari, 2021; Susanti, 2022). The problem that exists in grade V students of SD Negeri Reksosari 01, SD Negeri Reksosari 02 and SD Negeri Reksosari 03 is the low critical thinking skills of students which has an impact on low student learning outcomes. From the results of initial observations on learning mathematics of fractional calculation operations on the subject of fractional addition, students are still not able to understand the material well. This is shown by the large number of students who have not reached the Minimum Criteria of Mastery Learning.

This is proven that the critical thinking skills of grade V students of SD Negeri Reksosari 01, SD Negeri Reksosari 02, and SD Negeri Reksosari 03 are still low. SD Negeri Reksosari 01, which has 22 students, has an average critical thinking skill of 10.2 or 51.1% in the D (Less) category. SD Negeri Reksosari 02 which has 6 students, the average critical thinking skills are 10.3 or 51.7% in the D (Less) category. SD Negeri Reksosari 03 which has 13 students, the average critical thinking skills are 10.5 or 53% in the D (Less) category.

After conducting in-depth observations and interviews with teachers and students at these three schools, the low critical thinking skills of students are caused by several factors, including: (1) learning is still centered on teachers; (2) teachers do not use a variety of learning methods and media; (3) students have not been actively involved in learning; and 4) lack of motivation and interest in learning of students.use their knowledge to formulate a hypothesis, the collection of relevant information centered on students through discussions in

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a small group to get solutions to the given problems. Research by (Anugeraheni, 2018; Setiawan et al., 2023) found that PBL is able to improve students' critical thinking skills in elementary school with an average n-gain value of 0.75. Based on relevant research, PBL is effective in improving students' critical thinking skills in elementary school.

Based on preliminary data, the critical thinking skills of students at SD Negeri Reksosari 01, SD Negeri Reksosari 02, and SD Negeri Reksosari 03 are still low. As one of the alternative solutions that refer to the relevant research and the advantages of the e-module. The basic reason why researchers chose e-modules is to refer to relevant research results, that by implementing e-modules, learning becomes more interesting and increases students' motivation to learn. The material is not only presented in written form, but also in the form of video Students can think critically if stimulated with a problem in learning (Darmawati & Mustadi, 2023; Rahmadina, 2022) stated that Problem Based Learning (PBL) is a problem-oriented learning model, where the problem is used as a stimulus that spurs students to use their knowledge to formulate a hypothesis, the collection of relevant information centered on students through discussions in a small group to get solutions to the given problems and slowly affect the critical thinking skills of students in elementary school. Research by (Anugeraheni, 2018; Triswahyono et al., 2019) found that PBL is able to improve students' critical thinking skills in elementary school. Based on relevant research, PBL is effective in improving students' critical thinking skills in elementary school.

Based on preliminary data, the critical thinking skills of students at SD Negeri Reksosari 01, SD Negeri Reksosari 02, and SD Negeri Reksosari 03 are still low. As one of the alternative solutions that refer to the relevant research and the advantages of the e-module. The basic reason why researchers chose e-modules is to refer to relevant research results, that by implementing e-modules, learning becomes more interesting and increases students' motivation to learn. The material is not only presented in written form, but also in the form of video, audio or animation. Students no longer find it difficult to understand the material and think more critically about solving problems in daily life. For this reason, the researcher conducted a research on the development of PBL-oriented e-modules to improve students' critical thinking skills. this study aims to develop and validate a Problem Based Learning (PBL)-oriented e-module to improve elementary school students' critical thinking skills in mathematics.

METHODS

This study uses an R&D approach with the ADDDIE (Analysis, Design, Development, Implementation, and Evaluation) development procedure (Kruse, 2002; Peterson, 2003). The purpose is to analyze the procedure, validity and effectiveness of the development of PBL-oriented e-modules to improve critical thinking skills in fractional materials for grade V elementary school students. The research was conducted at SD Negeri Reksosari 01, SD Negeri Reksosari 02 and SD Negeri Reksosari 03, class V. The selection of teacher informant samples was carried out randomly and student informants used cluster random sampling techniques. The student research sample at SDN Reksosari 01 was 22 students, students at SDN Reksosari 02 were 6 students and students at SDN Reksosari 03 were 13 students. The data collection technique uses questionnaires, observations, and tests. The quality criteria for PBL-oriented e-modules on fractional calculation operation materials in improving the critical thinking skills of grade V students are: (1) the PBL-oriented e-module developed meets the validity of media experts, material experts, and learning experts if the average score from experts is at least 60%; (2) PBL-oriented e-modules are said to be Feasible if the average percentage achieved is greater than or equal to 70%; (3) The PBL-oriented E-module

developed is effective if there is a significant difference (p-value < 0.05) in critical thinking skills between the experimental group and the control group.

RESULTS AND DISCUSSION

The development of PBL-oriented e-modules for fractional calculation operations to improve fifth-grade students' critical thinking skills followed the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). In the analysis phase, we examined the mathematics learning media needs at SDN Reksosari 01 and SDN Reksosari 02 in Suruh District. This assessment revealed that students and teachers required PBL-oriented e-modules with clear, unambiguous instructions specifically tailored to fractional calculation operations.

During the design phase, we developed the e-module through four key steps. Initially, we selected appropriate software tools for development. Next, we created detailed storyboards for the PBL-oriented e-module focusing on fractional operations. We then developed assessment instruments for media, material, and learning experts to evaluate the e-module. Finally, we prepared a Learning Implementation Plan (RPP) incorporating the PBL-oriented e-module into classroom instruction.

The development phase involved validation by expert evaluators, followed by revisions and limited trials. The validation results are presented in Table 1. Figure 1 shows key examples of the developed e-module, including (A) the interactive problem-solving interface, (B) the multimedia-enhanced fraction operations tutorial, and (C) the student assessment dashboard.

Table 1. Validator Assessment

Validators	Validator Assessment
Validator 1 (mediar)	74%.
Validator 2 (material expert)	85%
Validator 3 (learning expert)	74,1%
Average	77,7 %

Figure 1. Examples of the Developed E-Module

After getting validity from the validator. The implementation of PBL-oriented e-modules is carried out on grade V students of SD Negeri Reksosari 01 and SDN Reksosari 02,

Suruh District, Semarang Regency. The results of the observation of grade V students of SDN Reksosari 01 can be shown in the following table 2:

Table 2. Observation Results of Grade V Students of SDN Reksosari 01

Indicators	Sum	Percentage
Students answer the problems presented	81	92
Students are active in group discussions	71	81
Students are actively seeking information	69	78
Students are active in the presentation of the results of the discussion	81	92
Students analyze and evaluate the results of the discussion	82	93
Average	87 %	

Based on the table 2, it shows that the learning of mathematics of fractional calculation operation material using PBL-oriented e-modules at SD Negeri Reksosari 01 obtained an average percentage of 87%. The average value of this percentage has met the targeted target of 70%. That way PBL-oriented e-modules can be called attractive. This is because students in learning show that they can answer the problems presented, students are more active in group discussions, students are more active in seeking information, students are more active in presenting the results of discussions, and students can analyze and evaluate the results of discussions. The results of the observation of grade V students of SDN Reksosari 02 can be seen in the following table 3.

Table 3. Observation Results of Grade V Students of SDN Reksosari 02

Indicators	Sum	Percentage
Students answer the problems presented	23	96
Students are active in group discussions	22	92
Students are actively seeking information	20	83
Students are active in the presentation of the results of the discussion	23	96
Students analyze and evaluate the results of the discussion	23	96
Average	93 %	

Based on the table 3, it shows that the learning of Mathematics material for Fractional Calculation Operations using PBL-oriented e-modules in grade V students of SD Negeri Reksosari 02, obtained an average percentage of 93%. The average value of this percentage has reached the expected target of 70%. That way, PBL-oriented e-modules applied in learning are called interesting. This is because students in learning appear to be able to answer the problems presented, students are more active in group discussions, students are more active in seeking information, students are more active in presenting the results of the discussion and students can analyze and evaluate the results of the discussion. Meanwhile, the results of observation in grade V students of SD Negeri Reksosari 03 totaled 13 students in mathematics learning fractional calculation operation material not using PBL-oriented e-modules can be shown in the following table 4.

Table 4. Observation Results of Grade V Students of SDN Reksosari 03

Indicators	Sum	Percentage
Students answer the problems presented	39	75
Students are active in group discussions	36	69
Students are actively seeking information	34	65
Students are active in the presentation of the results of the discussion	36	69
Students analyze and evaluate the results of the discussion	34	65
Average	69 %	

Based on table 4 above, it shows that the mathematics learning of fractional calculation operation material does not use PBL-oriented e-modules in grade V students of SD Negeri Reksosari 03, obtained an average percentage of 69%. The average percentage has not met the expected target of 70%. That way, learning mathematics without using PBL-oriented e-modules is called uninteresting. This is because students in learning show that they are rarely active in group discussions or looking for information, students are less active in the presentation of discussion results, and students are less able to analyze and evaluate the results of discussions.

The researcher carried out the last revision of the PBL-oriented e-module product developed referring to the response or field notes on the observation sheet. The results of the latest revision from media experts, material experts, and learning experts related to PBL-oriented e-module instruments , stated that the material experts consisted of 8 items of prototype assessment statements, with an average percentage of 85%. The assessment of media experts is an average percentage of 74%. The assessment of learning experts is an average percentage of 74.1%. That way, the average percentage of questionnaire assessments from the three validators is 77.7% > 70% (Criteria set), the results of the calculation can be read in the attachment. The percentage acquisition of 77.7% stated that the PBL-oriented e-module product in mathematics learning of fractional calculation operation material developed to improve critical thinking skills, was included in the category of Good or Suitable for use.

The average score of critical thinking skills of grade V students of SD Negeri Reksosari 01 and Reksosari 02, Suruh District shows that there is an increase after the implementation of PBL-oriented e-modules. Meanwhile, for grade V students of SD Negeri Reksosari 03 as a control group after learning again, it also increased. More details, the increase in the average score of students' critical thinking skills can be illustrated in the following graph.

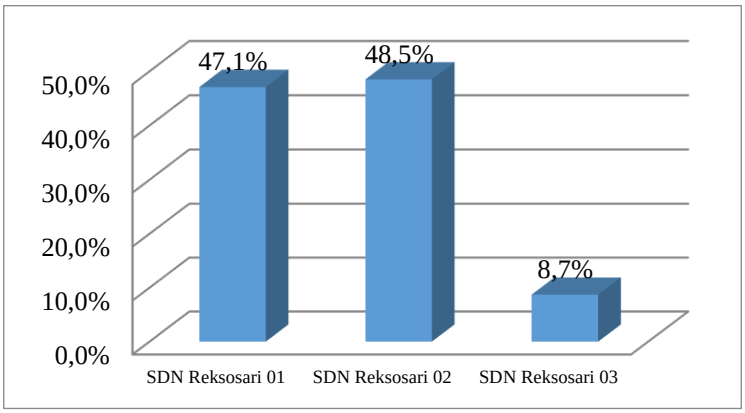

Figure 2. Graph of Average Score Improvement of Students' Critical Thinking Skills

Based on the figure 2, it can be explained that the average increase in critical thinking skills of grade V students of SD Negeri Reksosari 01, SD Negeri Reksoari 02, and SD Negeri Reksoari 03 Suruh District is the highest grade V students of SD Negeri Reksosari 02, which is 48.5% from the average pretest score of 10.3 to 15.3 (posttest).

The critical thinking skills of grade V students as an experimental group (using PBL-based e-modules), namely SD Negeri Reksosari 01 and SD Negeri Reksosari 02 in learning mathematics of fractional calculation operation material, showed better results than students in grade V of SD Negeri Reksosari 03 (control group) whose learning did not use e-modules PBL-oriented. From the results of the calculation with the SPSS program, it was obtained that the t-value was calculated = 11.043 with a p-value of 0.000 < 0.05 Thus, it can be seen that PBL-oriented e-module products have a significant effect on students' critical thinking skills. More details of the results of the Independent Samples Test with the help of the SPSS version 25.0 program can be illustrated in the following table 5.

Table 5. Independent Sample Test Results

Test Type	Group	t-value	df	Sig. (2-tailed)	Mean Difference	Std. Error	95% CI Lower	95% CI Upper
Equal variances assumed	Critical Thinking	11.043	39	0.000	3.953	0.358	3.229	4.677
Equal variances not assumed	Critical Thinking	12.029	29.029	0.000	3.953	0.329	3.281	4.625

Based on the table 5, it can be concluded that the p-value with a significant level α = 5%, is 0.000 < 0.05, then Ho is rejected and Ha is accepted, which means that there is a difference in critical thinking skills between the experimental group and the control group. Thus, it can be concluded that the development of PBL-oriented e-modules on students' fractional number operation materials is effective in improving the critical thinking skills of grade V elementary school students.

The development of PBL-oriented e-module products for fractional calculation operations has successfully improved students' critical thinking skills through the ADDIE development phases. The validator assessment showed promising results, with media experts giving an average percentage of 74%, material experts 85%, and learning experts 74.1%. The overall average of 77.7% exceeded the set criteria of 70%, indicating that the PBL-oriented e-module is suitable for implementation in mathematics learning, particularly for fractional calculation operations.

This e-module integrates problem-based learning principles with critical thinking characteristics as defined by (Mahmudah et al., 2022; Resnick & Resnick, 1992), including complex, non-algorithmic thinking, multiple solution pathways, and self-regulation. These align with Bloom's taxonomy revisions by (Anderson & Krathwohl, 2001), emphasizing synthesis, analysis, and evaluation skills. The implementation of these characteristics through PBL-oriented e-modules supports student-centered learning by providing real-world, unstructured problems that develop critical thinking capabilities.

Our findings align with several previous studies. Research by (Budiarti, 2016; Miftakhurrohmah et al., 2023; Noer, 2020) demonstrated that e-module-assisted guided inquiry effectively improved critical thinking skills compared to traditional methods. Similarly, (Feriyanti, 2019; Suparman, 2020) found that e-modules were feasible for

elementary mathematics instruction. Recent research by (Rahmadina, 2022) reported significant improvements in mathematical critical thinking skills (84.8%) and creative thinking skills (87.7%) using PBL-based e-modules. These results are further supported by (Asri, 2024; Maulina, 2022; Rahayu, 2022; Suharyat, 2023), who found that PBL-oriented e-modules effectively enhanced elementary students' critical thinking abilities.

The effectiveness of the PBL-oriented e-module was measured through carefully designed test instruments based on critical thinking indicators: (1) associating and identifying relevant data/information, (2) compiling conclusions from data/information, (3) evaluating statement quality/accuracy, (4) identifying process/product consistency with evidence, (5) using problem-solving strategies, and (6) developing new problem-solving alternatives. This assessment approach aligns with (Nieveen, 1999) three quality determinants: validity, practicality, and effectiveness.

The practical implementation was evaluated using both teacher and student questionnaires, along with observation sheets monitoring the e-module's use in learning processes. As (Huda, 2016) emphasized, PBL implementation extends beyond classroom instruction to curriculum development, transforming the traditional teacher-centered paradigm into student-centered learning. This transformation was evident in our study's results, where students demonstrated improved engagement and critical thinking capabilities.

Supporting these findings, (Buchori & Rahmawati, 2017) research on geometry e-modules with a Realistic Mathematics Approach showed similar positive outcomes in elementary mathematics learning. Our results extend these findings to fractional operations, demonstrating the versatility of well-designed e-modules across different mathematical concepts. This effectiveness is further validated by student responses, which showed positive engagement with the developed e-module, suggesting its potential for wider dissemination among elementary school teachers.

The significant improvement in critical thinking skills observed in our study (as shown in the statistical analysis) reinforces (Asri, 2024) assertion that appropriate learning media enables students to explore subject matter systematically. This systematic exploration is particularly crucial in mathematics education, where conceptual understanding builds upon previous knowledge. The successful integration of PBL principles within the e-module framework has created an effective tool for developing higher-order thinking skills in elementary mathematics education.

The statistical analysis of our intervention shows compelling evidence of the e-module's effectiveness. Our findings demonstrated significant improvements in critical thinking abilities when comparing experimental and control groups ($t = 11.043$, $p < 0.000$). The mean difference of 3.953 between groups indicates substantial improvement in students' critical thinking capabilities when using the PBL-oriented e-module. These quantitative results complement the qualitative feedback received from teachers and students, suggesting that the e-module successfully bridges theoretical understanding with practical application in mathematics learning.

The integration of technology through e-modules addresses several challenges identified in traditional mathematics instruction. As noted in our initial observations, students often struggled with abstract mathematical concepts, particularly in fractional operations. The PBL-oriented e-module provides interactive, contextualized learning experiences that make these abstract concepts more accessible. This finding aligns with (Suharyat, 2023) research highlighting e-modules' positive impact on learning outcomes and quality improvement in Indonesian education.

Furthermore, our implementation of the ADDIE model ensured systematic development and refinement of the e-module, addressing specific needs identified in the analysis phase. The iterative development process, supported by expert validation and user feedback, resulted

in a product that effectively combines technological accessibility with sound pedagogical principles. This methodological approach supports (Rahmadina, 2022; Saragih & Herlina, 2023)) findings on the importance of systematic e-module development in achieving desired learning outcomes. These comprehensive results suggest that PBL-oriented e-modules offer a viable solution for enhancing critical thinking skills in elementary mathematics education. The successful integration of problem-based learning principles with digital technology creates an engaging learning environment that promotes active student participation and higher-order thinking skills development.

CONCLUSION

Based on the results of the study, it can be concluded that the development of PBL-oriented e-modules was developed using the ADDIE (Analyze, Design, Develop, Implementation and Evaluation) stages. The average percentage of questionnaire assessments from the three validators was 77.7% > 70% (Criteria set). The percentage acquisition of 77.7% stated that the PBL-oriented e-module product in mathematics learning of fractional calculation operation material developed to improve critical thinking skills, was included in the category of Good or Suitable for use. Based on the independent sample test, it can be concluded that the p-value with a significant level $\alpha = 5\%$, is $0.000 < 0.05$, then Ho is rejected and Ha is accepted, which means that there is a difference in critical thinking skills between the experimental group and the control group. Thus, it can be concluded that the development of PBL-oriented e-modules on students' fractional number operation materials is effective in improving the critical thinking skills of grade V elementary school students.

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