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Development of teaching modules in improving mathematical critical thinking skills based on problem-based learning

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Abstract: The ability of grade VII students in mathematical critical thinking still needs to be improved so that a more effective learning approach is needed. The purpose of this study is to develop a teaching module to improve mathematical critical thinking skills based on Problem Based Learning (PBL). Research and Development (R&D) with the ADDIE (Analysis, Design, Development, Implementation, Evaluation) development model is used as a research method in this study. The teaching module instrument was then validated by two experts. The results of the two validators showed that the developed teaching module was valid. Then the developed teaching module was tested on a small group of students to determine the readability and practicality of the teaching module. The results of the trial showed that the developed teaching module was practical. In other words, it shows that the developed Problem Based Learning (PBL)-based teaching module is able to improve students' mathematical critical thinking skills.
Keywords: Problem Based Learning, Teaching Module, Critical Mathematical Thinking

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Introduction

Education plays a crucial role in developing various essential abilities, critical thinking ability is one of the abilities that must be realized. Critical thinking is a person's process of analyzing information in detail, making decisions, solving problems in a logical and structured manner (Facione, 2023). This ability is very important in learning mathematics, where students must understand and apply abstract concepts to solve various problems. Critical thinking improves the ability to think and face problems, one of which is in the learning process (Ardiansyah et al., 2022) (Evendi et al., 2022). 21st century learning in education requires 4C skills, including the ability to think critically (Supena et al., 2021). People with critical thinking skills are able to evaluate and find the validity of the information they receive in order to make logical decisions (Rahardhian, 2022) (Monteleone et al., 2023).

Mathematics learning does not only aim to master calculations, but also to build critical and analytical thinking skills. Research shows that approaches based on problem solving can significantly improve these skills (Palinussa et al., 2023). One of the effective methods is Problem Based Learning (PBL). Problem-based learning has the advantage of fostering critical thinking skills in mathematics, besides that it also helps students to be better at analyzing a problem (Sarwastuti & Purnomo, 2023). The problems presented in problem-based learning are mostly contextual problems so that students are required to develop critical thinking skills during the learning process (Triyanto & Mustadi, 2020).

Learning mathematics is important to develop critical thinking skills. Mathematical critical thinking is the ability to think critically in mathematics (Suparman et al., 2022). For now, mathematics teaching should be designed to improve students' critical thinking skills (Nugraha & Suparman, 2021) (Yuliani et al., 2021). Therefore, the goal of learning mathematics is to develop students' critical

thinking skills. Students should be able to think critically based on original content. Developing mathematical critical thinking skills allows them to make logical decisions and make the best choices for their problems (Al-Fanny & Roesdiana, 2019) (Firdaus et al., 2019). In line with (Rachmantika & Wardono, 2019) that mathematical critical thinking skills make it easier for students to identify, analyze, evaluate, reason and interpret information.

Facts in the field show that students' mathematical critical thinking skills still do not meet the expected targets (Zamzam et al., 2023) (Rohani et al., 2022). The learning delivered does not lead to problem solving so that students' ability to think critically mathematically has decreased (Benyamin et al., 2021) (Kusmaharti & Yustitia, 2022), the learning process is dominated by the teacher (Utomo & Hardini, 2023) (Ratnawati et al., 2020) (Rismayanti et al., 2022), the subject matter does not keep up with technological and scientific developments and does not support students in improving their critical thinking skills in mathematics (Dwijayanti et al., 2020). Based on the above problems, efforts are needed to improve mathematical critical thinking skills where learning is presented in the form of problems, especially in mathematics subjects.

The problem-based learning process can be presented in the form of teaching modules. (Handayani et al., 2022) in their research stated that teaching modules are learning tools that can help students to learn independently. Teaching modules contain learning objectives to be achieved, material, practice questions, and answers to questions (Setyaningsih & Mukodimah, 2022). Teaching modules allow students to regulate their own learning style and speed (Handayani et al., 2022). Although some previous studies, such as Handayani et al. (2022) and Dwijayanti et al. (2020), have shown that PBL-based modules can improve critical thinking skills, these studies have not specifically explored the effectiveness of these modules in the context of students at certain levels of education or certain regions. Therefore, this research seeks to fill this gap. Teaching modules utilize various elements, namely text, animation, images, and practice questions to increase student involvement and motivation in learning (Jannah et al., 2022).

PBL-based learning effectively improves students' critical thinking skills in mathematics. Teaching modules are also part of supporting students' critical thinking skills in mathematics. (Dwijayanti et al., 2020) suggest several factors can improve mathematical critical thinking skills, one of which is presenting material in the form of contextual problems with the help of teaching modules. In line with that, (Iswantara et al., 2023) explained that teaching modules help teachers to make learning materials interesting and interactive.

The use of PBL-based teaching modules can encourage students' mathematical critical thinking skills. The novelty of this research provides a unique contribution by applying PBL-based modules to mathematical learning contexts that have not been widely explored, especially in the Indonesian educational environment with a contextual approach and based on student needs. (Ramadanti et al., 2021) suggested that teaching modules can be arranged or formed based on the stages and syntax of PBL. The advantage of applying PBL-based teaching modules is that it helps students to think critically and build knowledge and correct concepts (Sarwastuti & Purnomo, 2023) (Syahlan & Simamora, 2022).

The main purpose of developing PBL-based teaching modules is to encourage students to improve their mathematical critical thinking skills. The hope is that students not only gain a better understanding of mathematical concepts, but also develop their critical thinking skills, and can solve everyday problems. Therefore, the development of this teaching module is expected to contribute to the development of the learning process, especially mathematics. This study aims to develop a Problem-Based Learning (PBL) based learning module that is effective in improving students' mathematical critical thinking skills. This module is designed to support students in understanding mathematical concepts in depth through a contextual and interactive problem-based approach.

Methods

The research method used in this study adapts from the Research and Development (R&D) method with the ADDIE development model with several phases including the first phase Analysis, the second phase Design, the third phase Development, the fourth phase Implementation, and the last phase Evaluation. The explanation of each phase is: (1) Analysis is a needs analysis conducted through surveys and interviews with teachers and students to find out the problems faced in learning mathematics and the need for teaching modules; (2) Design is designing PBL-based teaching modules which include learning objectives, materials, learning methods, and evaluation: (3) Development is developing modules based on the design that has been developed, then validated by media experts and material experts. (4) Implementation is to implement the teaching module in small groups involving seventh grade students as research subjects; (5) Evaluation is to evaluate the effectiveness of the module through mathematical critical thinking ability tests and questionnaires to determine student responses to the module. Six junior and senior high school students in Malang City were used as research subjects to test the readability level of the developed teaching module. The selection of participants was conducted using purposive sampling, focusing on students with varying levels of mathematical ability to ensure a diverse perspective on module readability. Further testing on a larger group of students will be conducted during the evaluation phase to assess module effectiveness. The data collection instruments used consisted of validation sheets, implementation sheets, and student response questionnaires.

Results and Discussion

This study aims to improve students' mathematical critical thinking skills through teaching modules based on Problem Based Learning (PBL) developed. Broadly speaking, this research is to see the responses of teachers and students to the teaching modules developed. The module developed is PBL-based which is adapted to the curriculum currently used, namely the independent curriculum. The images and illustrations presented in the teaching module are presented in an interesting and contextual manner.

The first phase is the analysis phase. The purpose of this phase is to collect data, observe and evaluate data about the problems and needs of students when learning math. This activity includes needs analysis, curriculum analysis, and materials used. The data analyzed were obtained from questionnaires and interviews with teachers. The analysis revealed that the school applies the independent curriculum. Furthermore, the information obtained shows that students have difficulty in mathematics. One of the causes is that learning is teacher-centered and students are more passive. As a result, students' critical thinking skills are limited, especially in mathematics (Utomo & Hardini, 2023); (Ratnawati et al., 2020); (Rismayanti et al., 2022).

Students' inability to solve math story problems is also one of the obstacles in learning. Students can only answer questions that have been previously exemplified. According to (Rizqiani et al., 2023), mathematical critical thinking skills are needed to solve mathematical problems. Interviews conducted also revealed that teachers need access to open resources which can increase student independence and engagement in learning. Teaching modules are one of the teaching materials where students can learn independently and increase activeness in the learning proces (Kusmaharti & Yustitia, 2022); (Zakiyah et al., 2019). This makes developing problem-based learning resources, especially PBL-based teaching modules, very necessary in improving students' mathematical critical thinking skills.

The second phase is the design phase. In this phase, PBL-based teaching modules were developed and designed according to PBL syntax and the suitability of materials or learning outcomes based on the independent curriculum. The teaching module developed is presented in Figure 1.

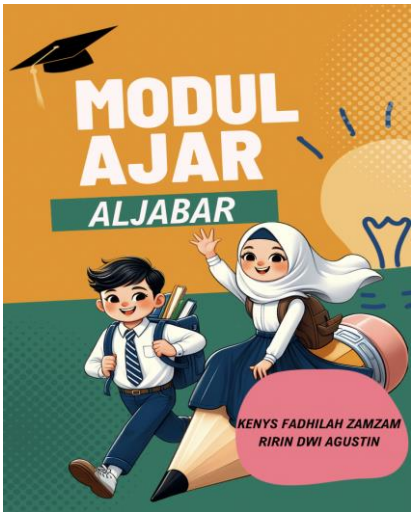

Figure 1. Module Cover

Figure 1 shows the cover of the PBL-based teaching module to improve students' mathematical critical thinking. The cover is designed to be as attractive as possible and adapted for junior high school / middle school children. The function on the cover of the teaching module is to attract students' attention to read the contents of the teaching module developed. The content of the teaching module is presented in Figure 2.

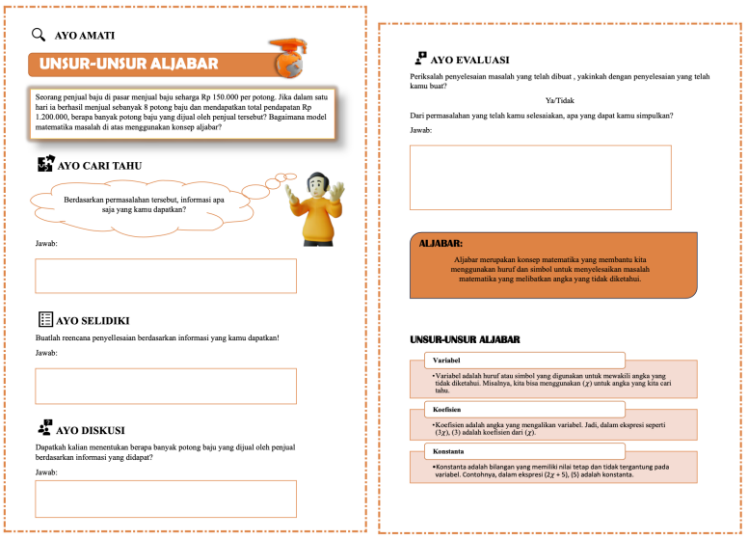

Figure 2. Teaching Module Content

Figure 2 shows the content of the developed teaching module. The developed module is PBL-based so that the module content is adjusted to the PBL syntax and adjusted to the independent curriculum where the learning process is more in activity. At the beginning of the material, a problem is given that will be observed by students. Then organize students to learn by finding out information obtained from a problem. Furthermore, guiding student investigations by providing “Let's investigate” space and providing discussion space for students to present the results of solving the problems given. The last step is evaluating the problem solving process. In line with several researchers who argue that students' mathematical critical thinking skills can be improved by applying PBL learning (Ratnawati et al., 2020); (Syahlan & Simamora, 2022); In addition, to strengthen the material, a summary of the material is given which is shown in Figure 3.

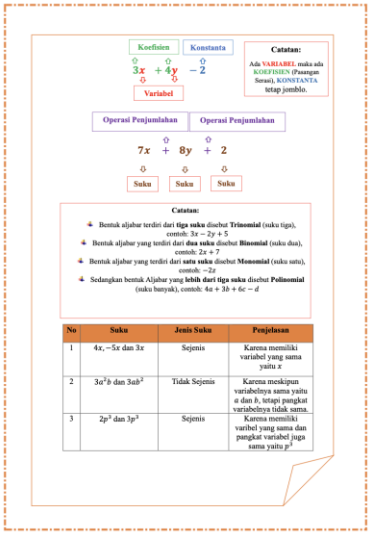

Figure 3. Reinforcement Material

Figure 3 shows the material reinforcement provided. The purpose of this material reinforcement is to help students better understand and master Algebra material and students will find it easier to find important information related to Algebra. In addition, practice problems are presented to improve students' mathematical critical thinking skills which are shown in Figure 4.

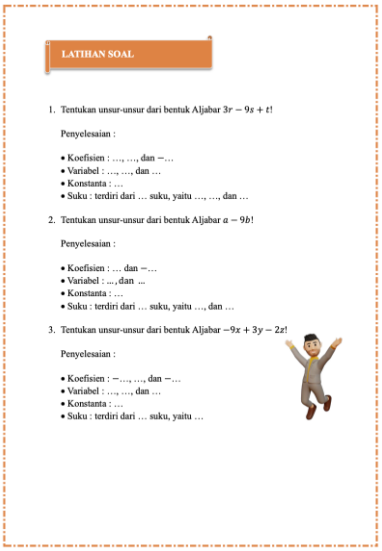

Figure 4. Practice Questions

Figure 4 shows an exercise problem. The mathematical critical thinking ability of junior high school students can be seen when students solve math problems on Algebra material (Pramuditya et al., 2019). Furthermore, in his research (Sachdeva & Eggen, 2021) stated that students need to be encouraged to think critically through problem solving where one way is given practice problems. One of the impacts of students often solving problems is to make students more insightful and improve their mathematical critical thinking skills.

The third phase is the development phase. In this phase, product validation and revision were carried out. Validation of the teaching module was carried out by two experts, namely material experts and media experts. The results of the two validators were used as notes for further improvement. Validation by experts needs to be done that the module that has been developed is in accordance with the expected indicators (Nindiasari et al., 2022). Based on the results of material experts and media

experts, the development of teaching modules in improving mathematical critical thinking skills based on Problem Based Learning is valid so that it is suitable for use and ready to be disseminated for testing. The recapitulation of the results of the validator of the teaching module development instrument in improving mathematical critical thinking skills based on problem-based learning is shown in Table 1.

Table 1. Recapitulation of Validator Results

Indicator	Average	Description
Breadth of material	4,6	Very valid
Suitability of teaching modules based on Problem Based Learning	3,9	Valid
Readability	4,2	Very valid

The next stage is a small-scale trial to determine the practicality of the developed module. The instrument used to determine the practicality is the module practicality sheet. This trial was conducted on 7 junior high school students in Malang City. The results of the trial showed a score of 86.20%. This score indicates that the developed module is practical in its use. Practical module users will find it easier to understand the content and improve learning outcomes for users. In line with (Tobing et al., 2021) suggested that the developed module can improve students' ability in higher order thinking, one of which is mathematical critical thinking. Modules developed based on PBL can make students focus more on problems and find alternative solutions in solving them (Islahiyah et al., 2021). (Nugraha & Suparman, 2021) adding PBL can help students in improving critical thinking, which includes the ability to analyze, process, and show the truth of the information obtained. Thus, the use of PBL-based teaching modules contributes to improving students' mathematical critical thinking skills.

Conclusion

This study produced a valid and practical PBL-based module to improve students' mathematical critical thinking skills. This module not only meets the validity criteria but is also practically proven to improve critical thinking skills in the context of mathematics. The results showed that the most significant increase in mathematical critical thinking skills was seen in the Elementary Clarification indicator which was included in the high category, showing that students were able to identify, formulate, and clarify mathematical problems well. Meanwhile, other indicators such as Inference, Basic Support, and tactics and strategies are in the medium category, indicating that although there is an improvement in providing basic support for arguments, making inferences, and planning and implementing strategies, the level of improvement is not as high as the Elementary Clarification indicator. Another important finding is that this module can be recommended for the development of other mathematics learning materials. The characteristics of the mathematics modules developed in this study provide guidelines that can be adapted for different topics and levels of education.

Suggestions for future research are to focus more on improving indicators of mathematical critical thinking skills that are in the moderate category, especially on the inference indicator. More in-depth attention to how learners make inferences will help strengthen their overall critical thinking skills in mathematics. This research not only provides a practical contribution through the development of an effective PBL module, but also provides important insights for further development in the field of critical mathematics education.

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