



Developing An Interactive Chemistry E-module Based on Problem-based Learning to Improve Critical Thinking Skills of High School Students

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Abstract: This study aims to develop an interactive chemistry E-module based on problem-based learning (PBL) to improve the critical thinking skills of high school students in class X and measure its feasibility. This research used the research and development method with the ADDIE model, which consists of 5 stages (Analysis, Design, Development, Implementation, and Evaluation). The tools used in this study were test tools and non-test tools, namely modified BSNP standard verification sheets and essay questions. The data analysis techniques used in this research were qualitative and quantitative. The results of the feasibility test from the materials specialist instructors, and chemistry teachers, as well as media specialists, an average result of 82.7% met the "very fair" criterion. An average result of 93.12% met the "highly feasible" criterion. Based on classroom learning experiments, the E-module can improve students' critical thinking skills by achieving an N gain value of 0.48 in the medium category. It was also evidence of a 55% increase in students' average critical thinking ability score using electronic modules and belonging to the critical category. When learning with the E module, a significant difference occurs at the significance level $=0.000$.

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Introduction

In the era of Revolution 4.0, which promotes changes in the educational world, the government has implemented the revised curriculum 2013 to meet the educational needs of the 21st century through current developments and student characteristics. In implementing the 2013 revised curriculum guidelines, there is a need to promote learning by integrating four elements: character education, which requires teachers' creativity, literacy, 21st-century skills, and strengthening higher-order thinking skills (Mulyasa, 2018).

Critical thinking skills are part of analytical or higher-order thinking skills. These skills include the ability to analyze arguments, draw conclusions using inductive or deductive reasoning, judge or evaluate, and make decisions or solve problems (Suardana et al., 2018). Three critical thinking competencies include recognizing assumptions, generating arguments, and drawing conclusions. It is clear that critical thinking is essential for classrooms, workplaces, and especially for everyday life, but the teaching and evaluation applied in the school environment to stimulate critical thinking skills is not enough (Changwong et al., 2018). It means that efforts are still needed to improve students' critical thinking. Student-centred learning is one of the features of his 2013 curriculum in Indonesia. It has been suggested that while teachers function as facilitators, students can actively process the information they receive during teaching and learning activities (Priyambodo et al., 2022). Critical thinking skills are especially needed when analyzing problems and finding solutions.



Additionally, the 2013 curriculum equips students with higher-order thinking skills, also known as complex thinking, consisting of critical thinking, creative thinking, problem solving, and decision-making in the cognitive or knowledge domain. is required to be attached to (Nuri et al., 2021). Critical thinking skills can be applied, trained and developed through learning processes and assessment. Critical thinking skills are defined as a process of intellectual discipline that reflects consistency in thought and action(Ijirana, Sitti Aminah, Supriadi, 2022).

The chemistry learning process requires considering three main aspects: products, processes, and scientific attitudes (Sriwahyuni, 2022). However, students often still find chemistry difficult to understand because chemistry is abstract (Timilsena et al., 2022). This results in students having a poor understanding of chemical concepts, even if abstract facts are part of the explanation of concrete facts or concepts (Üce & Ceyhan, 2019). One of the chemicals learn in Class X is electrolyte and non-electrolyte solutions. Based on the characteristics of electrolytic and non-electrolytic solution materials, including factual, conceptual and procedural knowledge, the research results of (Yenti, 2020) show that some students find it difficult to understand electrolytic and non-electrolytic solution materials., shows that it remains difficult, especially in grouping. Convert the solution to a strong electrolyte, weak electrolyte, or non-electrolyte and write the ionization reaction equation. Ninety-five percent of the difficulties students face in electrolyte and non-electrolyte solutions materials are solving problems that require a thorough understanding of concepts and reaction equations. Reactions of ions in solution require student understanding, so advanced thinking and analysis are required to build and relate the concepts given (Nahadi *et al.*, 2020). Mastery of concept is abstracted as the basis for critical thinking, decision making and problem-solving abilities (Lismayani et al., 2017). A learning model that can facilitate students' analysis and thinking processes is problem-based learning (PBL).

In order to introduce the PBL model into the learning process, teaching materials are essential as learning resources that bring together the competencies and support the achievement of the learning objectives set in the curriculum. The materials are expected to facilitate student insight and act as a guide to follow the steps in each presented material (Sitepu & Pulungan, 2021). In research conducted by (Narmaditya et al., 2018) the results show that students' abilities in critical thinking have increased during the learning process. It is shown by an increased ability to solve problems and make conclusions through critical thinking processes. Applying Problem-Based Learning also encourages students to have critical thinking skills in various activities, such as asking questions, discussing problems, and creating solutions. When developing educational materials, they must comply with the requirements of the accreditation body, namely the National Board for Educational Standards (BSNP) and the applicable curriculum (Dibyantini & Sulastri, 2022). It's the one form of educational material is modules.

With the development of information technology in the 4.0 era, there is a need to provide paper-based teaching materials and interactive teaching materials that include text, images, and audio with electronic support. For example, the development of educational materials in electronic modules (e-modules) (Ningsih & Fuadiah, 2022). The background description above attracts researchers' attention to research the development of electronic modules (E-modules) by integrating them with PBL learning models, animated videos, and interactive quizzes so that students participate actively in learning and can improve their critical thinking skills.



Research Method

This research was conducted using the research and development method with a development research design from the ADDIE model (Analysis, Design, Development, Implementation, Evaluation) (Sofnidar & Yuliana, 2018). Researchers developed a product in the form of a PBL-based electronic module for high school students in class X semester II using the Kvisoft Flipbook Maker application. This research was carried out at Muhammadiyah 1 Medan Private High School. The research was conducted in May, even the semester of the 2022/2023 academic year. The samples in this study were 2 chemistry teachers, 2 chemical subject matter experts, 2 media experts and 50 students divided into two classes X Science. This research and development used several methods to collect data: interviews, questionnaires, and pretest-posttest questions.

The research instrument used was a questionnaire as a checklist sheet with a Likert scale, which refers to BSNP rules. The pretest and post-test were compared to determine whether the product effectively improved students' critical thinking skills. The instrument is structured essay questions totalling 10 questions relating to electrolyte and non-electrolyte solutions. The data analysis techniques used in this research are qualitative and quantitative. Qualitative data contains input, suggestions and responses from validators, data obtained based on BSNP questionnaire validation and student responses processed using descriptive statistics, while the quantitative data is in the form of an assessment of critical thinking skills, which is tested by calculating the average (mean) results of students' pretest and posttest. An N-Gain value analysis is carried out to determine the increase in critical thinking skills. To find out whether there are differences in the critical thinking abilities of students who use e-modules, an independent t-test was carried out.

Results and Discussion

Analysis

The analysis stage is the most important stage in the development process. To carry out the analysis stage we have to analyze four things, such as we have to analyze the needs of students, analyze the curriculum related to basic competencies, determine instructional objectives, and analyze learning objectives (Aldoobie, 2015). E-module product development began with the analysis stage. This stage included an analysis of needs and the curriculum used by the school. Based on the results of the analysis, the teaching materials used were only textbooks, and the obstacle faced by teachers in the learning process is not using textbooks and only using the lecture method, making students more passive and inactive due to monotonous learning. It means not having enthusiasm. Observations showed that students tended to be passive in the learning process. It could be seen when the teacher asks questions during learning. Students were silent and must pay more attention to what the teacher says. The methods and models used in learning need to follow the recommendations of the curriculum. Learning model innovation requires teacher skills. Using good models can significantly improve students' skills, attitudes, and knowledge. The 2013 curriculum recommends the Problem-Based Learning (PBL) model. Namely a problem-based learning model that can optimize students' thinking abilities. PBL is a model that focuses learning on students and can increase student knowledge and help students with difficulty learning. This model begins with a real problem or question that students must solve through investigation and application (Ridwanulloh et al., 2022). Therefore, more interactive, and innovative teaching materials are needed so that students can participate actively in the learning process.



Design

The design phase is the next step in the ADDIE model. This phase considered how design instruction could be truly effective in a way that facilitates people's learning and interaction with the materials created and provided. In the design stage the focus is on designing assessments for the topic, choosing the form of the course, and creating teaching strategies (Aldoobie, 2015).

At the design stage, PBL-based interactive e-modules are created according to the results of curriculum analysis, needs analysis and previously used teaching materials. The design of the module content material follows the PBL syntax, namely consisting of (1) orienting students, (2) organizing student learning, (3) guiding individual and group investigation, (4) developing and presenting results, and (5) analyzing and evaluating problem-solving processes (Hakim et al., 2016). These parts are integrated into the module and packaged using professional PDF flip software and will be uploaded online with the help of a flipbook maker. The e-book display is made as interactive as possible, including pictures, learning videos, quizzes and evaluation questions that students can work on directly, and students can see directly the results of working on the questions and their corrections. A learning process can be said to be successful if it succeeds in changing the student's perspective in a controllable direction, making it easier for the student to understand problems and phenomena that were initially considered difficult because they were very abstract (Mulyaningsih & Saraswati, 2017). Therefore, e-modules with the help of a flipbook maker are considered one of the best solutions for making teaching materials come alive by adding pictures, videos and other interactive quizzes. In this research, the E-module has been integrated into the problem-based learning (PBL) learning model, an innovative learning model that can provide active learning conditions for students. This learning model supports the continuity of learning with the 2013 Curriculum, as it involves students solving problems through the steps of the scientific method and learning how to solve problems. We can learn problem-related knowledge while acquiring problem-solving (Qurniati et al., 2020).

Development

In the development stage, the e-module that had been designed was developed. The PBL-based interactive e-module was validated by expert lecturers, namely two material expert lecturers and two media expert lecturers; the material was also validated by chemistry study teachers, namely three teachers. A feasibility test was carried out to determine the feasibility percentage of the module developed using a validity test. Validity testing was carried out using an instrument in the form of a validation sheet designed and modified following BSNP references.

Materials and media experts validate PBL-based interactive e-modules to determine whether the developed e-modules are suitable for use in the learning process, considering the BSNP standards. Based on the verification results by three chemistry instructors, the average feasibility is 82.75%, the average feasibility by three chemistry teacher verifiers is 86.25%, and the average feasibility by two media expert verifiers is 93.12%. Although some aspects of the E module need modification, we can conclude that the E module is suitable for use, including (1) the color contrast in the e-module must be improved so that the display is clearer, (2) the use of margins in the e-module must be consistent, (3) Correct some writing errors. Improvements are made based on suggestions and input from validators, followed by implementation.



Table 1. Expert Lecturer Validator Results

No.	Assessment Components	Mean	Percentage	Criteria
1.	Content Eligibility	3,27	81,75%	Worthy
2.	Language Eligibility	.3,21	80,25%	Worthy
3.	Feasibility of Presentation	3,47	86,75%	Worthy
Mean		3,31	82,75%	Worthy

Table 2. Study Field Teacher Validator Results

No.	Assessment Components	Mean	Percentage	Criteria
1.	Content Eligibility	3,49	87,25%	Worthy
2.	Language Eligibility	3,35	83,75%	Worthy
3.	Feasibility of Presentation	3,53	88,25%	Worthy
Mean		3,45	86,25%	Worthy



Figure 1. Valid E-module

Implementation

At the e-module implementation stage, it was used in an experimental class with 25 students. The materials taught in the implementation of Young's modulus were electrolyte and non-electrolyte solutions. Before learning begins, a pre-test is conducted, after which students are divided into six groups of four to five students each. Discussion materials will be provided to students as per the module instructions. Next, you will be asked to discuss the results of your discussion, compile it into a report, and present it to the class. Other listeners are asked to respond, and at the end of the lesson, students are asked to answer post-test questions. The pre-and post-test test instruments consist of 10 essay questions representing each measure of critical thinking. The device was first validated by experts, namely an expert lecturer and a chemistry teacher, and on ten students learning electrolytic and non-electrolytic solutions. Of the 20 questions submitted for verification, ten were valid, and ten were invalid. Second, to determine whether there is a difference in students' critical thinking skills when learning using the developed problem-based learning e-module compared to students who did not use the e-module.



Evaluation

An evaluation phase was conducted. Additionally, the N-Gain test improved students' critical thinking skills. Based on the N-gain test, we found that the N-gain of the control class was 0.24 in the low category, and the N-gain of the experimental class was 0.48 in the medium category. This means that the improvement in students' critical thinking skills in the control class is relatively small. In contrast, improving students' critical thinking skills in the experimental class is rated as moderate. Developing an interactive chemistry e-module based on problem-based learning improves students' critical thinking ability and makes the e-module highly effective for learning.

Hypothesis testing of critical thinking skills with significance level $\alpha = 0.05$. The test performed in this study was an independent t-test with a significance value smaller than the value ($0.000 < 0.05$), meaning H_a was accepted. It can be concluded that there is a significant difference in the critical thinking skills of students who use interactive electronic modules based on problem-based learning compared to those who do not. It means that students using electronic modules' average critical thinking ability score increased by 55%, which puts them in the important category. In contrast, the control class's score increased by only 35%, which puts them in the less important category. It has also been proven that.

Interactive E-modules based on problem-based learning can improve students' critical thinking skills. It is proven in research conducted by Musa (2023) who states that the learning process using PBL can improve students' critical thinking skills. Using a problem-based learning model, we can engage students in a critical thinking process based on their experiences, improving their critical thinking skills (Rahmat et al., 2020).

Implementing electronic modules using PBL-based mobile phones increases students' interest in learning. It is consistent with research findings that interesting learning is caused by the learning model used in the learning process. In addition, teachers' teaching materials are equipped with functions and learning levels that can support students' independent learning and learning during the school learning process. This research shows that using the right learning model and interesting teaching materials can help students with learning difficulties and encourage them to improve their critical thinking skills. Problem-based learning is a learning model that can actively involve students in the learning process (Jamilah et al., 2023). Applying the PBL model in e-modules can help direct students to learn independently.

Conclusion

The conclusion obtained from the results of this study for the materials specialist instructors, chemistry teachers, as well as media specialists an average result of 82.7% met the "very fair" criterion. An average result of 93.12% met the "highly feasible" criterion. Based on classroom learning experiments, the E-module can improve students' critical thinking skills by achieving an N gain value of 0.48 in the medium category. It is also evidence of a 55% increase in students' average critical thinking ability score using electronic modules and belonging to the critical category. When learning with the E module, a significant difference occurs at the significance level $\alpha = 0.000$.

Recommendation

For further research, the author suggests adding interesting games that can be played directly by students to hone students' memory and concentration skills. Books can also be packaged in a more interesting form and provide convenience; e-modules can also be accessed offline



so that students who have difficulty Networking can also open and learn with enthusiasm. Teachers can use interactive e-modules to attract students' attention in the learning process, especially in chemistry learning. So that learning can take place effectively and efficiently.

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