



Implementation of Problem Based Learning E-Module to Improve Students' Critical Thinking Skills in Green Chemistry

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Received: June 08, 2023

Revised: December 12, 2025

Accepted: August 25, 2026

Published: August 31, 2026

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DOI: [10.29303/jppipa.v12i8.4179](https://doi.org/10.29303/jppipa.v12i8.4179)

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Abstract: Technology development affects the quality of learning activity, so it needs some IT-learning-based media development. The purpose of the research to determine the effectiveness of using Problem Based Learning (PBL) e-modules in improving students' critical thinking skills in green chemistry Class X SMA/MA. This study was a quasi-experimental by using a nonequivalent control group design. The samples of the study consisted of 2 classes, namely X₁ and X₂. The sampling technique is a purposive sampling technique. The analysis results using independent sample t-test showed a significance value of $0.000 < 0.05$. The data analysis results of critical thinking skills used N-gain score test; the experimental class obtained a score of 0.72, in which it belonged to the high category. Meanwhile, the average N-gain score for the control class was 0.47, in which it belonged to the medium category. It can be concluded that there is a significant difference in the students' critical thinking skills between the experimental class and the control class. Therefore, the implementation of Problem Based Learning e-module can be an alternative to improve the students' critical thinking skills in green chemistry Class X SMA/MA.

Keywords: E-module; Green chemistry; Problem based learning

Introduction

Education is the spearhead of the progress of a nation. Good education must follow the development of science and technology. It is intended that graduates from the education system can become successful individuals in the increasingly competitive 21st century. One of the goals of 21st century education is to improve students' critical thinking skills. According to Nugraha et al. (2017), Usman et al. (2024), Iwan et al. (2024), and Jamaluddin et al. (2023), critical thinking is an important ability needed to solve problems for students who want to live successful, responsible lives to face current and future challenges. Facione (2020) explains that the essence of critical thinking is part of cognitive abilities. The ability to think critically is very important for students to have along with the development of science and technology, because students must be able to critically filter information that is very easy to access, so that they can easily digest good or bad information. One

of the efforts to develop students' critical thinking skills is to use learning models, one of which is Problem Based Learning.

According to Novianti et al. (2020), the problem based learning model is a teaching model that is characterized by real problems as a context for students to learn critical thinking and problem solving skills and gain knowledge. Ariyatun et al. (2020), in their research it can be concluded that the application of the problem based learning model has a significant influence on students' critical thinking abilities. Research conducted by Dibyantini et al. (2023) with the title Development of Problem-Based E-Module Teaching Materials on Students' Critical Thinking Abilities on Reaction Rate Material proves that problem-based e-modules can improve students' critical thinking abilities.

Research conducted by Farenta et al. (2016) with the title Developing an E-Module Based on Problem Based Learning for Chemistry Subjects for Class X Students of

How to Cite:

Sari, F., Erna, M., & Noer, A. M. (2026). Implementation of Problem Based Learning E-Module to Improve Students' Critical Thinking Skills in Green Chemistry. *Jurnal Penelitian Pendidikan IPA*, 12(8), 83–87. <https://doi.org/10.29303/jppipa.v12i8.4179>

SMA Negeri 8 Malang shows that the learning media is valid and effectively used in the learning process.

Research conducted by Istiqomahet al. (2022) with the title Development of a Science Flipbook E-Module Based on Problem Based Learning on Environmental Pollution Material that E -The science flipbook module based on problem-based learning on environmental pollution material has a very valid level of validity in the aspects of content, language and graphics ($k=1.00$). Test responses of teachers and students to the E-module display obtained an average percentage of 93.75% and 86.41% in the very good category. These results indicate that the resulting E-module is ready to be used for classroom learning. Research conducted by Kimianti et al. (2019) with the title Developing a Science E-module Based on Problem Based Learning to Improve Critical Thinking Abilities proves that a science E-Module based on problem based learning to improve critical thinking skills is feasible, practical and effective in improving critical thinking abilities. One of the technology-based teaching materials that can be selected is an electronic module (e-module). Research conducted by Rahmadona et al. (2023) with the title Developing an e-Module Based on Problem Based Learning to Improve Students' Critical Thinking with the Help of Flip Pdf & Wordwall on Electrolyte and Non-Electrolyte Solution Material proves that The media developed is based on PBL and has the potential to improve students' critical thinking skills and get positive responses from students by Students.

Research conducted by Suparno et al. (2019) with the title Development of an Integrated Science Module Based on Problem Based Learning with a Movement Theme to Improve Students' Critical Thinking Abilities proves the effectiveness of the module in improving students' critical thinking abilities. -average score 0.6 with medium criteria. E-Modules can be packaged in digital form, added with interesting features such as audio, learning videos.

According to Novianti et al. (2020), the problem based learning model is a teaching model that is characterized by real problems as a context for students to learn critical thinking and problem solving skills and gain knowledge. According to Pratiwi et al. (2020), Problem Based Learning requires students to work together with other students to solve a problem, which can develop students' critical thinking abilities. According to Rosmasari et al. (2021), Seibert (2021), Aslan (2021), and Fidan et al. (2019) the Problem Based Learning model is a learning model that optimizes students' thinking abilities through systematic group or group learning activities, so that students can hone, improve, develop and test their thinking abilities.

Chemistry is a science that has unique and varied characteristics. One of the Chemistry materials in the

Merdeka Curriculum is Green Chemistry. Green Chemistry is an approach to solving environmental problems both in terms of the chemicals produced, the process and the reaction stages used. This material is very close to everyday life, so students are expected to have critical thinking skills. The purpose of the research is to determine the effectiveness of using Problem Based Learning (PBL) e-modules in improving students' critical thinking skills in green chemistry Class X SMA/MA. Hypothesis of this study is that there is a difference on the students' critical thinking skill between the control and experimental classes.

Method

The method of study that carried out was quantitative method. This study was a Quasi-Experimental study using non-equivalent control group design. This study was conducted on February until March 2023. The location of this study was in SMA Negeri 1 Siak Kecil, Bengkalis. The samples of this study were obtained thru a purposive sampling technique. According to Sugiyono (2021), the purposive sampling technique is a technique for sampling data sources with certain considerations. There were 56 students used as the samples of this study, of which students were the students of X1 and X2 at SMA Negeri 1 Siak Kecil in the academic year of 2022/2023.

Data analysis techniques for normality test used Kolmogorov-Smirnov test and statistical analysis was done by examining the hypotheses using the independent sample t-test, in which it was assisted by SPSS 23 program and the withdrawal of the conclusion was in the significance level of 5%. If the significance level was > 0.05 , the H_0 was rejected and the H_a was received. From the t-test results, there would be differences in the students' critical thinking skills before and after using the e-module. Furthermore, it would be analyzed to categorize the type of increase using the N-Gain test with the categories in Table 1.

Table 1. Category of N-Gain (Hake, 1998)

Value	Category
$g \geq 0.7$	High
$0.3 \leq g < 0.7$	Medium
$g < 0.3$	Low

Result and Discussion

At the implementation stage, a large-scale trial was carried out which aims to determine the effectiveness of using Problem Based Learning (PBL) green chemistry e-modules in improving students' critical thinking skills in green chemistry material through critical thinking ability test questions in the form of essays of 10

questions. The control and experimental classes were obtained from the homogeneity test results for classes X1 and X2 based on the TP odd semester exam scores 2022/2023 with the help of the SPSS 23 application. These two classes were given different treatment, namely, the experimental class used Problem Based Learning (PBL) based e-modules on green chemistry material as teaching materials, while the control class used textbooks/package books. Based on the results of the homogeneity test, it is known that class data X1 and X2 have a homogeneous variance, this is due to the value (sig) > 0.05, namely $0.079 > 0.05$. If the significant value is greater than 0.05, then the variances of the two or more groups are the same. So in this study class X1 and X2 as a trial class.

Normality Test

Kolmogorov-Smirnov test at a significance level of alpha 0.05 with the help of SPSS 23 software. It is known that the pretest and posttest score data for control and experimental classes both have sig values 0.200 whose value is (sig) > 0.05 so it can be concluded that the data is normally distributed.

Homogeneity Test

It was found that the sig. $0.568 > 0.05$, it can be concluded that the critical thinking ability scores of the control and experimental classes have a homogeneous variance.

Hypothesis Testing

It is known that the results of the t-test with df 54 note that the value of $t = 13.717$ with sig. (2-tailed) of $0.000 < 0.05$, meaning that H_a is accepted and is H_o rejected. So, it can be concluded that there are significant differences in the critical thinking abilities of students in the control and experimental classes.

At the evaluation stage, the N-Gain test was carried out. The results of the N-Gain analysis above show that the N-Gain value of the experimental class is higher than that of the control class. The control class has an N-Gain value of 0.47 in the medium category, the experimental class has an N-Gain value of 0.72 in the high category.

Based on the results of the analysis of the 6 indicators of students' critical thinking abilities, it can be concluded that the use of Problem Based Learning (PBL) based e-modules can influence the improvement of critical thinking abilities. Students' critical thinking abilities from 6 indicators that have high N-Gain scores in the experimental class include 4 indicators, namely: analysis, inference, explanation and self-regulation. Meanwhile, in the control class, the indicator of critical thinking ability that received the low category was interpretation. This is because students are not guided in finding problems. The other indicators are in the

medium category. Judging from the average N-Gain score, the experimental class got a score of 0.73 in the high category, while the control class had an average N-Gain score of 0.47 in the medium category.

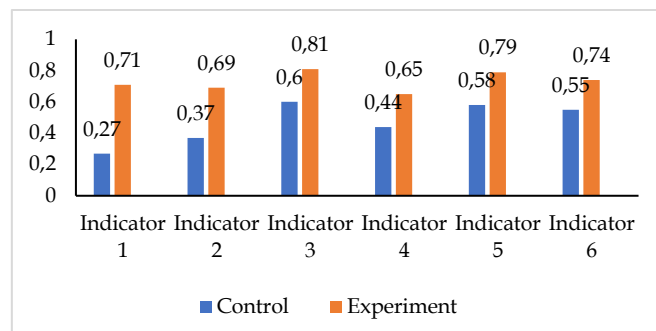


Figure 1. Graph of n-gain score analysis results critical thinking ability test with indicators: interpretation, analysis, inference, evaluation, explanation and self-regulation

The results of the N-Gain analysis above show that the N-Gain value of the experimental class is higher than that of the control class. The control class has an N-Gain value of 0.456 in the medium category, the experimental class has an N-Gain value of 0.7182 in the high category. There was an increase in students' critical thinking skills in the experimental class because in the experimental class the teaching materials used were e-modules based on Problem Based Learning, while in the control class learning used school textbooks as teaching materials, so that students gained learning experience and received explanations. In addition to the videos in the e-module apart from the explanation given by the teacher.

Conclusion

Based on the results of research and discussion, it can be concluded: (1) E-module based on Problem Based Learning (PBL) on green chemistry material was declared effective in improving students' critical thinking skills based on the Independent Sample T-Test with the result that there was a significant difference in students' critical thinking abilities in the control and experimental classes; (2) The improvement of students' critical thinking skills after using the Problem Based Learning (PBL) E-module on green chemistry material based on the N-Gain Score test obtained an increase of 0.72 in the high category.

Acknowledgments

Thank you to all parties who have helped in this research so that this article can be published.

Author Contributions

All authors contributed to writing this article.

Funding

No external funding.

Conflicts of Interest

No conflict interest.

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