

## **Students' Critical Thinking Skills Using an E-Module Based on Problem-Based Learning Combined with Socratic Dialogue**

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<i>Keywords</i>	<b>Abstract</b>
critical thinking skills, e-module, problem-based learning, Socratic Dialogue, environmental change	This study aimed at testing the effectiveness of an e-module based on Problem-Based Learning combined with Socratic Dialogue on the topic of environmental change in improving school students' critical thinking skills. This research was a quasi-experimental study and used a non-randomised control group, pre-test/post-test design. The sampling technique was cluster random sampling. The sample in this study was two experimental classes ( $n = 72$ ) and two control classes ( $n = 72$ ). The data collection instruments included multiple-choice tests and a questionnaire. The test results were analysed using the t-test and the N-gain score test. The results showed significant difference in students' critical thinking skills between the experimental and control classes. Students who used the e-module showed better critical thinking skills. Students who used the e-module showed a greater increase in critical thinking skills after the learning process, compared to students who did not use the e-module. Thus, it can be concluded that the e-module based on PBL combined with Socratic Dialogue effectively improved students' critical thinking skills.

### **Introduction**

Critical thinking skills are abilities that students must have to face the challenges of the 21st century. Geisinger (2016) and Tseng (2020) state that critical thinking skills are one of the cognitive abilities needed in the 21st century. The rapid development of knowledge has caused a shift in the focus of educational institutions from developing theoretical knowledge to developing thinking abilities or skills, one of which is the ability to think critically (Memiş & Akkaş, 2020; Sadhu & Laksono, 2018). It is no longer possible for teachers to equip students with all the knowledge and information available. Learning should train students to be able to access accurate and reliable information and to be able to think critically about that information.

Learning in the 21st century also demands the use of technology in teaching and learning activities. Caton et al. (2022) state that technology has changed learning landscapes and changed the way students and teachers think, interact and process information. E-modules are a form of technology utilisation that can make the learning process more interesting and interactive, can be done anytime and anywhere and can improve the quality of learning (Handayani et al., 2021). Enke et al. (2015) define modules as teaching materials that are systematically arranged (including material, method and evaluation) and are independent to achieve certain expected competencies.

Environmental change is one of the topics that must be mastered by students in Grade X. Haniyya and Bintari (2017) state that this material has an important role in instilling cognitive



skills and attitudes related to environmental problems around students. The need to raise environmental awareness cannot be separated from the environmental crisis due to irresponsible human activities (Sueb & Damayanti, 2021). Education plays a big role in teaching students how to study and investigate their environment and make intelligent as well as informed decisions about how to take care of it (Frantz & Mayer, 2014).

Research studies show that students' critical thinking skills are still low. The results of the initial tests conducted by the researchers showed that the average score of students' critical thinking skills was 48.84. This is supported by the trend in PISA results for Indonesian students, which were still below average (OECD, 2014; 2016; 2019; 2023). The results of previous studies by Elisanti et al. (2018) and Widodo et al. (2019) also showed that the average value of students' critical thinking skills in Biology subjects was still low (below 50). Based on the results of interviews with Biology teachers in schools, it was known that learning in the classroom was still dominated by teachers and did not develop students' critical thinking skills. This is consistent with the findings of Saputri et al. (2018) and Suyamto et al. (2018), who found that classroom learning was still teacher-centered and has not adequately trained students in critical thinking skills to meet the demands of the 21st century.

The results of preliminary studies conducted by researchers indicate that the main teaching materials used were textbooks. This is in line with previous research by Haka et al. (2020) and Safitri et al. (2021), which revealed that the teaching materials used by teachers were still dominated by textbooks. The results of the analysis showed that the textbooks used in class have not been able to foster students' critical thinking skills. The results of the survey conducted by researchers showed that 78.8% of students thought that the textbooks used on the topic of environmental change had limitations and weaknesses.

Critical thinking skills can be improved by applying the appropriate learning model. Asyari et al. (2016) and Bezanilla et al. (2019) state that learning models that facilitate decision-making and problem-solving activities can encourage students to think critically. When solving problems, students must make decisions, which might help them learn to be critical of their choices. Problem-Based Learning (PBL) is a learning model that facilitates these two activities so as to improve students' critical thinking skills (Asyari et al., 2016; Sebatana & Dudu, 2021).

The Socratic Dialogue is a questioning technique that can be applied in PBL learning. According to Hung (2011), many students struggle with the transition from traditional to PBL-based learning. In PBL learning, teachers use questions to help students overcome existing challenges. According to Katsara and De Witte (2019), Socratic Dialogue is a questioning technique that can help students learn while also improving their critical thinking skills.

## **Literature Review**

### **Critical Thinking Skills**

The concept of critical thinking was first put forward by John Dewey, who defined critical thinking as a process of active, persistent and thorough consideration of every belief, based on the reasons that support it and further conclusions that tend to follow (Dewey, 1933). Facione (1990) states that critical thinking is a metacognitive process that focuses on the judgment that aims to generate interpretation, analysis, evaluation and inference, as well as an explanation based on consideration of the evidence, concept, method, criteria or context that forms the basis of that judgment. According to Facione (2015), critical thinking skills consist of six aspects: interpretation, analysis, evaluation, inference, explanation and self-regulation.

**Problem-Based Learning (PBL)**

PBL is a student-centered learning model where students develop various solutions to problems that are often encountered in real life (Aslan, 2021; Suwono et al., 2021; Tarhan & Ayyildiz, 2015). The PBL model uses ill-structured problems, which allow students to explore several reasonable solutions and determine the most appropriate solution to solve the problem (Hung, 2015). Ill-structured problems allow students to engage in critical thinking processes, such as looking for alternatives and considering other points of view (Kim et al., 2013).

The PBL model according to Arends (2012) is divided into five learning stages: (1) orienting students to the problem; (2) organising students for study; (3) assisting independent and group investigation; (4) developing and presenting artefacts and exhibits; and (5) analysing and evaluating the problem-solving process. The third stage of PBL is the core of the PBL model, where students carry out investigative activities to make explanations and determine solutions (Arends, 2012).

**Socratic Dialogue**

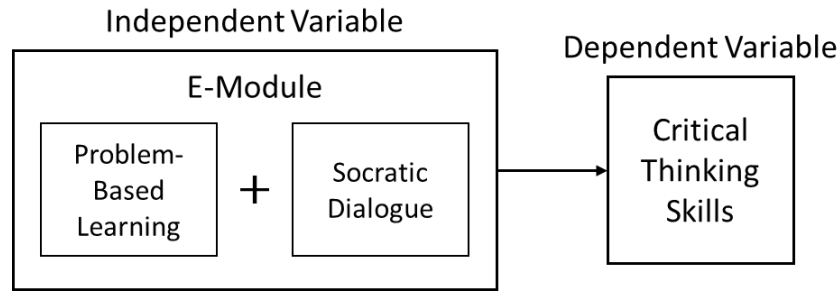
Socratic Dialogue is a method that comes from the habit of conversation carried out by the ancient Greek philosopher Socrates, to guide his students to understand a concept (Pangestika, et al., 2017; Vyskočilová dan Praško, 2012). Socratic Dialogue is a learning technique in which the teacher utilises a series of questions to stimulate and guide students' thinking rather than provides students with large amounts of information through direct instruction (Chin, 2007). The categories of questions in the Socratic Dialogue according to Paul (Lee et al., 2014) are questions of clarification, questions that probe assumptions, questions that probe reasons and evidence, questions about viewpoints or perspectives, questions that probe implications and consequences and questions about the question.

Socratic Dialogue uses systematic exploratory questions to trigger critical thinking on complex concepts (Martin et al., 2021; Paul & Elder, 2007). Exploratory questions invite responses without predetermined answers (Teo, 2016), allowing students to express themselves freely. Cui and Teo (2023) state that through exploratory questions, teachers not only explore what students know but also what and how they think. Teachers focus more on reasoning than knowledge, so as to encourage students' critical thinking.

**Topic: Environmental Change**

The topic of environmental change contains environmental problems that are close to student life. This material can encourage students to realise and understand environmental problems that occur in everyday life and find solutions to solve these problems. Priyadi and Suyanto (2019) state that problems in environmental change topic are real-life problems that must be solved by applying several concepts and principles. The environmental change topic has characteristics that are in accordance with the PBL model. The topic of environmental change applied to PBL can improve students' critical thinking skills through activities to solve environmental problems that occur in everyday life.

## Conceptual Framework



**Figure 1: Conceptual Framework of the Study**

The conceptual framework of this study is presented in Figure 1. In this study, critical thinking skills were trained through the application of an e-module. This study combined the PBL model with Socratic Dialogue questions, which were then integrated into an e-module. The learning process was carried out in accordance with the stages of the PBL model. Socratic Dialogue questions were inserted in the PBL stages to guide students in solving problems and to develop their critical thinking skills.

## Research Questions

The overarching objective of the study was to test the effectiveness of an e-module based on Problem-Based Learning combined with Socratic Dialogue on the topic of environmental change in improving students' critical thinking skills. Specifically, the following questions were formulated:

1. What is the difference in students' critical thinking skills between classes that use an e-module and those that do not use the e-module?
2. How is the comparison of students' critical thinking skills before and after the learning process in classes that use the e-module and those that do not use the e-module?
3. How is the student's response to the implementation of the e-module?

## Methods

### Research Design

This study was quasi-experimental. The research design used was a non-randomised control group, pre-test/post-test design. This design was chosen for this study because in carrying out the research it would not be possible to randomly assign subjects to treatment groups. Instead, this study used groups that already exist in schools, namely class groups (Ary et al., 2010), which were then used as the experimental classes and the control classes. The experimental classes were given a learning treatment with the implementation of the e-module based on PBL combined with Socratic Dialogue. The control classes conducted PBL learning using teaching materials commonly used in class.

### Participants

The research was conducted at a high school in Karanganyar, Central Java, Indonesia. The population in this study comprised all students in Grade X, which consisted of 12 classes ( $n = 422$ ). The age of the students was between 15 and 16 years old. The sampling technique in this study was cluster random sampling. The samples in this study were four classes, namely two

experimental classes ( $n = 72$ ) and two control classes ( $n = 72$ ). Before the sample class was selected, a normality and homogeneity test was first carried out to find out whether each class could be used as a representative sample of the population. The normality test was carried out using the Kolmogorov-Smirnov test ( $\alpha = 0.05$ ). The homogeneity test was carried out using Levene's test ( $\alpha = 0.05$ ). The test was carried out with SPSS 25. The test results showed that the population was normal and homogeneous.

### **Data Collection Tools**

The data collection techniques used were test and non-test techniques. The test technique was used to obtain data on students' critical thinking skills. The test instrument was arranged based on aspects of critical thinking skills according to Facione (2015), i.e., interpretation, analysis, evaluation, inference, explanation and self-regulation. The test consisted of 24 multiple-choice questions. Each aspect of critical thinking skills was measured by four items. The test instrument was tested for validity by material experts on environmental change and educational evaluation experts. Test questions were also tested for validity and reliability using the Rasch model. All items met the criteria for evaluating the validity of the items, which included the values of the outfit mean square (MNSQ), outfit Z-standard (ZSTD) and point measure correlation (PTMEA Corr). The results of the reliability test showed that the items had good reliability based on Cronbach's alpha (0.70) and very good reliability based on item reliability (0.91).

The non-test technique was used to obtain response data from experimental classes students after the implementation of the e-module based on PBL combined with Socratic Dialogue. The instrument used was a questionnaire. The questionnaire consisted of 16 statement items. The questionnaire contained statements about the presentation of the material, learning activities, Socratic Dialogue questions, and the use of the e-module. Statements in the questionnaire were measured using a Likert scale with the criteria of strongly agree (score 4), agree (score 3), disagree (score 2), and strongly disagree (score 1).

The main data in this study was student test results. The test data provided an overview of the level of students' critical thinking skills before and after the learning process in both the experimental classes and the control classes. Non-test data was used as supporting data that strengthened student test results. Through non-test data, it can be seen how students respond to the implementation of the e-module, whether the e-module made the learning process easier or more difficult for them.

### **Characteristics of the e-Module based on PBL combined with Socratic Dialogue**

The e-module used in this study was developed based on the development procedure according to Borg and Gall (1983). Learning activities in the e-module were structured based on the five PBL stages according to Arends (2012). Socratic Dialogue questions were inserted in the first, second and third stages of the PBL model. Socratic Dialogue was presented in the form of a series of questions that aimed to guide students during learning activities and trained them to have critical thinking skills.

The e-module consisted of the following components: (1) cover page; (2) Francis page; (3) table of contents; (4) e-module description; (5) e-module usage guide; (6) competencies that must be achieved; (7) concept map; (8) learning activities; (9) glossary and (10) bibliography. The e-module was developed in the form of a flipbook. Flipbooks are easily accessible to students and can be accessed online or offline using smartphones or laptops (Mutiarra & Emilia, 2022; Sumarmi et al., 2021). Flipbooks are more interactive in nature because they are not

limited to only text but can also contain images, videos, audio and links (Mutiara & Emilia, 2022).

### Procedure

The research was started by giving a pre-test to the experimental classes and the control classes. The pre-test was conducted to measure students' critical thinking skills before being given treatment. The treatment was then given to the experimental classes, which was the implementation of the e-module based on PBL combined with Socratic Dialogue. The control classes conducted PBL learning using the teaching material that was usually used. The learning process was carried out three times, with a duration of 90 minutes each. Then the post-test was given to both classes to measure students' critical thinking skills after the learning process. Questionnaire was given to experimental classes after the implementation of the e-module.

### Data Analysis

The analysis technique used to determine the effectiveness of the e-module based on PBL combined with Socratic Dialogue in improving critical thinking skills was the t-test and the N-gain score test. The t-test was preceded by a prerequisite test, namely the normality test and homogeneity test. The normality test was carried out using the Kolmogorov-Smirnov test ( $\alpha = 0.05$ ). The homogeneity test was carried out using Levene's test ( $\alpha = 0.05$ ).

The t-test ( $\alpha = 0.05$ ) aimed to test the significance of difference in students' critical thinking skills. The t-test was carried out using SPSS 25. The t-test that was carried out was an independent sample t-test because the data came from two different groups. The t-test compared the post-test results of the experimental classes and the control classes.  $H_0$  stated that there was no difference in students' critical thinking skills between the experimental and control classes, while  $H_1$  stated that there was a difference in students' critical thinking skills between the experimental and control classes. The criterion used in making a hypothesis decision was the t value.  $H_0$  was rejected if the  $t_{\text{count}}$  value was greater than  $t_{\text{table}}$  ( $t_{\text{count}} > t_{\text{table}}$ ).

The N-gain score test aimed to determine the increase in students' critical thinking skills based on a comparison of pre-test and post-test results. The N-gain score test was used when there was a significant difference in post-test results between the experimental classes and the control classes. The formula used to calculate the N-gain score is as follows:

$$\text{N-gain score} = \frac{\text{post-test average score} - \text{pre-test average score}}{\text{maximum score} - \text{pre-test average score}}$$

The N-gain score calculation results were then interpreted using the category (Hake, 1999) presented in Table 1.

**Table 1: Category of N-Gain Score**

N-Gain Score	Category
$g \geq 0.7$	High
$0.7 > g \geq 0.3$	Medium
$g < 0.3$	Low

## Findings

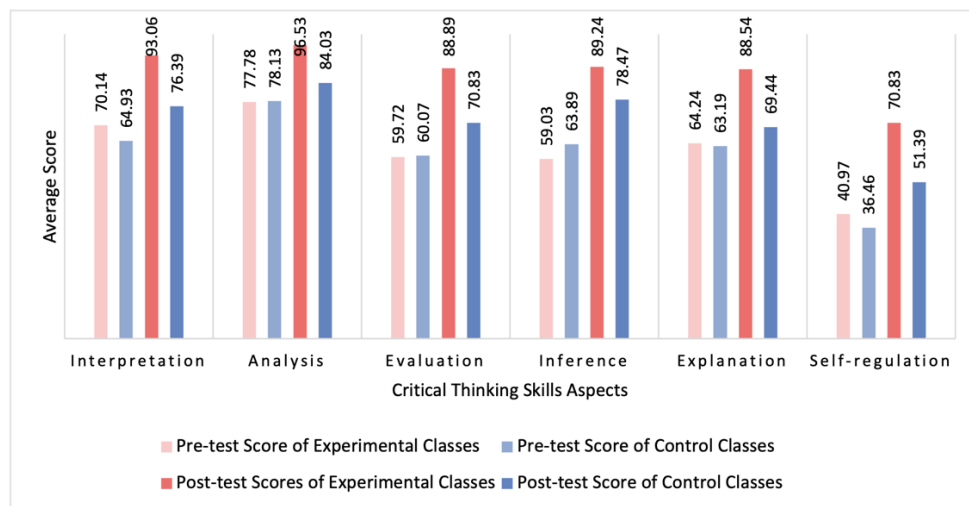
Data on critical thinking skills obtained from the results of the pre-test and post-test are presented in Table 2.

**Table 2: Data on Students' Critical Thinking Skills**

Statistic Result	Experimental Classes		Control Classes	
	Pre-test	Post-test	Pre-test	Post-test
N	72	72	72	72
Mean	61.98	87.85	61.11	71.76
Median	62.50	87.50	62.50	70.83
Variance	46.43	55.14	56.23	50.00
Standard Deviation	6.81	7.43	7.50	7.07
Minimum	45.83	70.83	45.83	58.33
Maximum	75.00	100.00	83.33	87.50

Table 2 shows that the pre-test average scores in the experimental classes (61.98) and the control classes (61.11) were not much different, which shows that students' initial critical thinking skills in both classes were equivalent. The post-test average score of the experimental classes (87.85) was higher than that of the control classes (71.76). The post-test median value of the experimental classes (87.50) was also higher than the control classes (70.83). The maximum and minimum scores in the experimental classes post-test (100 and 70.83) were higher than those in the control classes post-test (87.50 and 58.33). Based on these results, in general, it can be said that students' critical thinking skills in the experimental classes using the e-module were better than in the control classes.

A comparison of pre-test and post-test results between the experimental classes and the control classes for each aspect of critical thinking skills is presented in Figure 2.



**Figure 2: Comparison of Pre-test and Post-test Results between the Experimental Classes and the Control Classes on Each Aspect of Critical Thinking Skills**

Based on Figure 2 it is known that there was an increase in the average score of each aspect of critical thinking skills in the experimental classes and the control classes. The post-test average score of the experimental classes on each aspect of critical thinking skills was higher than that of the control classes. In the experimental classes post-test, the highest average score was the aspect of analysis (96.53) and the lowest average score was the aspect of self-regulation (70.83). Data on students' critical thinking skills scores were then analysed using the t-test and the N-gain score test.

***Research Question 1: What is the difference in students' critical thinking skills between classes that use the e-module and those that do not use the e-module?***

The normality and homogeneity test results show the post-test score data was normal and homogeneous, so the prerequisites for the t-test have been fulfilled. The results of the t-test are presented in Table 3.

**Table 3: Results of the t-Test on the Post-test Scores of Critical Thinking Skills for the Experimental Classes and Control Classes**

Class	Mean	$t_{\text{count}}$	Sig.	$t_{(0,05;142)}$	Result	Test Decision
Experimental	87.85	13.314	0.000	1.97681	$t_{\text{count}} > t_{\text{table}}$	$H_0$ rejected
Control	71.76					

Table 3 shows that  $t_{\text{count}}$  is greater than  $t_{\text{table}}$  ( $13.314 > 1.97681$ ), so  $H_0$  was rejected, and it can be stated that there was a significant difference in critical thinking skills between the experimental and control classes. The post-test average score of the experimental classes (87.85) was higher than that of the control classes (71.76), so it can be seen that students' critical thinking skills were better in classes using the e-module based on PBL combined with Socratic Dialogue.

***Research Question 2: How is the comparison of students' critical thinking skills before and after the learning process in classes that use the e-module and those that do not use the e-module?***

The results of the N-gain score test are presented in Table 4.

**Table 4: Results of the N-Gain Score Test on the Post-test Scores of Critical Thinking Skills for the Experimental Classes and Control Classes**

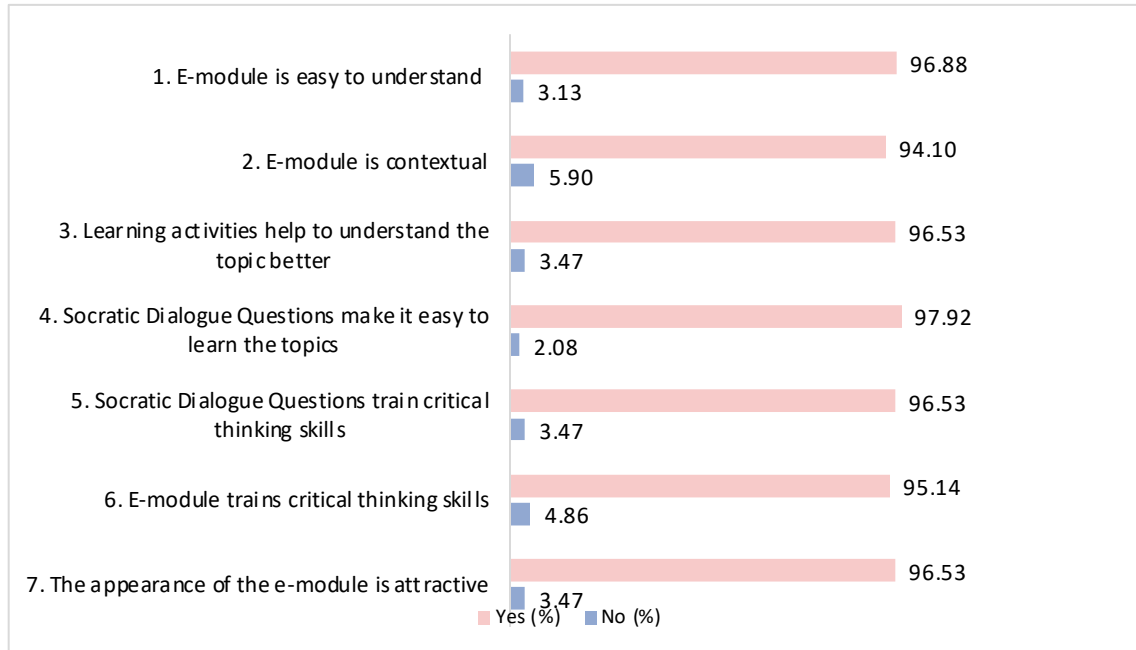
Class	N-Gain Score	Category
Experimental	0.68	Medium
Control	0.27	Low

Table 4 shows that there was a difference in the N-gain score between the experimental classes and the control classes. The experimental classes had an N-gain score of 0.66 (medium). The control classes had an N-gain score of 0.29 (low). The average score of students in the experimental classes obtained a greater increase after learning using the e-module compared to the control classes.



**Research Question 3: How is the student's response to the implementation of the e-module?**

The results of the student response questionnaire to the implementation of the e-module are presented in Figure 3.



**Figure 3: Students' Response to the Implementation of the E-Module Based on PBL Combined with Socratic Dialogue**

The results of the questionnaire in Figure 3 show that the e-module was easy for students to understand. The explanations on the e-module were equipped with pictures and examples of application in everyday life so that students could more easily understand the topic. The topic presented was related to students' real-world situations, and learning activities in the e-module encouraged students to make connections between their knowledge and its application in everyday life. The learning activities in the e-module also helped students understand the topic of environmental change better. Socratic Dialogue questions in the e-module made it easier for students to study the topic. Socratic Dialogue questions played a role in guiding students during learning activities. Students argued that the e-module could empower critical thinking skills. Socratic Dialogue questions in the e-module could also encourage students to think critically.

### Discussion

The results of the t-test conducted on the post-test scores showed significant difference in critical thinking skills between the experimental and control classes. The post-test average score of the experimental classes (87.15) was higher than that of the control classes (71.53), so it could be seen that students' critical thinking skills were better in classes using the e-module. The results of the N-gain score test showed that the experimental classes had an N-gain score of 0.66 (medium), while the control classes had an N-gain score of 0.29 (low). This showed that the increase in students' critical thinking skills was greater in the experimental classes than in the

control classes. The results of the t-test and N-gain score test showed that the e-module based on PBL combined with Socratic Dialogue effectively improved students' critical thinking skills.

The e-module based on PBL combined with Socratic Dialogue applied in this research encouraged students to become active learners. In the e-module, there were learning activities where students were guided to solve environmental problems that occurred in the environment where they lived. Gale et al. (2022) stated that critical thinking skills are very important in all aspects of problem-solving. Problem-solving is impossible without an element of critical thinking. Critical thinking serves to limit bias and encourage an unbiased viewpoint (Lamont, 2020). Critical thinking skills can help students understand problems in depth and identify the factors that cause problems. This ability also helps students generate appropriate hypotheses and can lead to solutions that can solve the problem completely. Thus, it can be concluded that the e-module in this study fostered students' critical thinking skills through problem-solving activities.

The results obtained in this study are in line with previous studies. Research conducted by Gholami et al. (2016) and Hursen (2021) showed a significant increase in critical thinking skills after implementing the PBL model. This study applied the PBL model digitally, namely through an e-module, which could be accessed using smartphones or laptops. Tudor Car et al. (2019) explained that digital-based PBL was more effective in developing skills compared to traditional learning. Research conducted by Ismail et al. (2018) showed that the PBL model integrated into mobile applications had a positive effect on students' critical thinking skills. Research conducted by Kinney (2022) and Lee et al. (2014) showed that the use of Socratic Dialogue questions was effective in improving students' critical thinking skills.

Even though there have been many previous studies regarding empowering critical thinking skills through the application of the PBL model or Socratic Dialogue, there is still very little research combining the PBL model and Socratic Dialogue. This study combined the PBL and Socratic Dialogue models into an e-module, which aimed to guide students' learning processes and encourage students' critical thinking skills. The results obtained from this study could be used as a starting point and study material for further research regarding the PBL model combined with Socratic Dialogue.

### **Conclusion and Recommendations**

The results of the data analysis showed significant difference in students' critical thinking skills between the experimental and control classes. Students who used the e-module showed better critical thinking skills. Students who used the e-module showed a greater increase in critical thinking skills after the learning process compared to students who did not use the e-module. The results of the questionnaire showed that the e-module helped students understand the topic of environmental change better and developed their critical thinking skills. Thus, it can be concluded that the e-module based on PBL combined with Socratic Dialogue effectively improved students' critical thinking skills.

This study was limited to environmental change material. Further research could be conducted to improve students' critical thinking skills on other topics in Biology. In addition, this study focused on measuring students' thinking skills. Effective critical thinking requires both ability and willingness (i.e., critical thinking dispositions) to implement higher-order cognitive processes (Facione, 2000; Halpern, 1999). Individuals who possess certain personality dispositions (for example, open-mindedness, intellectual curiosity and skepticism) are more likely to implement critical thinking skills in everyday life (Thomas & Hayes, 2021). Further research could be conducted to investigate students' critical thinking dispositions.

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