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(Research/ Review) Article

The Effectiveness of Predict-Observe-Explain (POE) Based E-Modules to Improve Critical Thinking Skills on Chemical Equilibrium

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Abstract: This study aims to analyze the effectiveness of e-modules based on Predict-Observe-Explain (POE) to improve students' critical thinking skills on chemical equilibrium material. The subjects in this study were students of Senior High School 4 Surabaya. This type of research is pre-experimental with a one-group pretest-posttest design. The research data were obtained from the pretest and posttest results of critical thinking skills. Data analysis technique using the Paired Sample t-Test. The study's results based on the Paired Sample t-Test showed a P-Value of 0.000 (<0.05). Thus, it can be concluded that e-modules based on POE are effectively used to improve students' critical thinking skills on chemical equilibrium material.

Keywords: E-Module; Predict-Observe-Explain (POE); Critical Thinking Skills; Chemical Equilibrium

1. Introduction

Education is an individual learning process to develop one's character regarding ethics, norms, and customs. Education is an important part of life in a global society, including Indonesia [1]. Indonesia has demonstrated its commitment to enhancing the quality of education, as evidenced by the implementation of the Merdeka Curriculum. Informed by the Merdeka Curriculum, chemical equilibrium material is included in the Learning Outcomes phase F. In these learning outcomes, one of the materials studied is chemical equilibrium. Learning stages are obtained based on these learning outcomes, including visualizing and explaining a phenomenon through observation, data collection, analysis, and conclusion. Phase F allows students to dig deeper into chemical concepts, both theoretically and practically, where chemistry is a science that studies the transformation and energy needed [2].

Students stated that chemistry lessons were complicated, some of the reasons stated by students were that there were too many formulas, the material was confusing and not meaningful, the teacher explained only briefly and in less detail so that students did not understand the material, the learning methods used by the teacher were complicated for students to understand, and the learning media only used books [3]. The results of a pre-research questionnaire distributed to 35 Senior High School 4 Surabaya students revealed that 68.57% of students stated that chemistry lessons were difficult to understand, particularly in the context of chemical equilibrium studies. A challenging topic for students in chemistry is chemical equilibrium, primarily due to its abstract concepts, so it requires direct observation of the phenomena that occur to understand it [4]. Students have difficulty understanding the equilibrium shift sub-material because they use Le Chatelier's principle without understanding it [5]. Le Chatelier's principle is the foundation for answering questions about shifting equilibrium, but if students do not understand the principle, they will have difficulty understanding the equilibrium sub-material [6]. Therefore, in learning chemical equilibrium material, it is necessary to provide opportunities for students to build their knowledge through critical thinking skills because it is closely related to the phenomena around them. In

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the 21st century, every learner is expected to have four main skills as the output of education: critical thinking, creativity, collaboration, and communication. One of the main pillars in the 21st century is the ability to think critically. The Merdeka Curriculum emphasizes the enhancement of the Pancasila learner profile, aiming to elevate the quality of education in Indonesia with a focus on character development [7]. Critical thinking is one of the aspects of the Pancasila learner profile. Students who engage in critical thinking may objectively digest information, integrate disparate data, analyze content, assess validity, and formulate conclusions [8].

According to Facione, critical thinking skills abilities include interpretation, analysis, inference, evaluation, explanation, and self-regulation, which collectively serve the purposes of substantiating a case, elucidating events, and addressing problems [9]. Critical thinking can help learners understand concepts and materials because it allows them to participate in the discovery of concepts actively, consequently, the knowledge gained from critical thinking can be stored in long-term memory [10]. In this study, critical thinking skills are the indicators of critical thinking skills, as per Facione. However, they focus on five indicators: interpretation, analysis, inference, explanation, and self-regulation.

Based on the results of pre-research on chemistry learning at Senior High School 4 Surabaya, it is known that students' critical thinking skills in the interpretation and analysis indicators show a low category, which is 49.76% and 47.86%, respectively. At the same time, the inference and evaluation indicators show a very low category, which is 37.14% and 19.29%, respectively. This is derived from teacher interviews, indicating that critical thinking skills are hardly imparted to pupils. In educational activities, teachers must cultivate critical thinking abilities in student to enhance the quality of their cognitive processes and facilitate effective learning.

These issues may be resolved by using teacher strategies and utilizing relevant teaching resources to help students comprehend the chemical content being covered. One of the learning models in accordance with the Merdeka Curriculum and the critical thinking skills component is the POE learning model. The POE learning model facilitates opportunities for learners to create their own conceptual experiences by reconciling and negotiating between existing knowledge and new information [11]. This learning model requires students to predict a phenomenon, conduct observations through experiments, and articulate the alignment of predictions with the experimental outcomes [12]. In summary, learning strategies that utilize POE can enhance the critical thinking skills of students.

The POE learning approach requires suitable instructional materials to enhance the teaching and learning experience. This is required by the demands of the Merdeka Curriculum, where students are required to be active in learning and can learn independently with the help of internet media. One type of teaching material commonly used in the learning process is a learning module, which is usually used for independent learning that allows students to learn systematically without depending on others [13].

The POE based learning module was developed with the aim of training students' ability to experiment by interacting directly with the environment [14]. Module into a digital form that can be accessed through a computer/laptop or smartphone, containing videos and other animated content [6]. One application that can help make e-modules is Flip PDF Professional, a software useful for making electronic books [15].

Based on the analysis of these problems, this research was formulated to improve students' thinking skills. This research is entitled "The Effectiveness of Predict-Observe-Explain (POE) Based E-Modules to Improve Students' Critical Thinking Skills on Chemical Equilibrium Material". The e-module used is expected to be used by teachers as a reference or one of the effective materials to improve critical thinking skills. In addition, it can also be used by students as a learning resource to improve the quality of chemistry learning and motivate students in learning chemistry.

2. Preliminaries or Related Work or Literature Review

Critical thinking skills are important to familiarize learners with because with critical thinking skills, a person will be able to think deeply and thoroughly about problems within the range of their experience [16]. In constructivism theory, teachers not only reinforce learners but also provide opportunities for learners to find their own ideas. However, in reality, the lack of critical thinking skills of learners is found in both national and international education [12].

This condition is exacerbated by the conventional learning approach and the lack of utilization of interactive learning media, especially in chemistry subjects. Chemical equilibrium material is one of the topics that is considered difficult, abstract, and less interesting for students, which impacts their low involvement and critical thinking skills.

Several studies have shown that the POE learning model effectively improves critical thinking skills and learner activity [4]. The POE model provides a learning experience that encourages learners to make predictions, observations, and explanations of a phenomenon, which aligns with an active and constructive learning model [12]. However, the POE learning model must also be supported by appropriate teaching materials to optimize the teaching and learning process. One of the teaching materials commonly used in learning is learning modules. Learning modules based on POE learning strategies are developed with the aim of training students' experiential skills by interacting directly with the environment [14].

In the digital era, the need for interactive, flexible, and easily accessible teaching materials is becoming increasingly important. E-modules that are based on POE have the potential to effectively address these requirements by offering learning experiences that are contextual, independent, and consistent with the characteristics of 21st-century learners. Unfortunately, until now, there are still limited studies that specifically examine the effectiveness of POE based e-modules in improving students' critical thinking skills, especially on complex chemical equilibrium materials that require strong conceptual understanding. Therefore, this research is important to fill this void and contribute to developing chemistry learning innovations that are more effective and relevant to the times.

3. Proposed Method

This study implemented e-modules based on POE to enhance students' critical thinking skills regarding chemical equilibrium material. The research design used in these types of research is pre-experimental, specifically a one-group pretest-posttest design. The research design is shown in Figure 1.

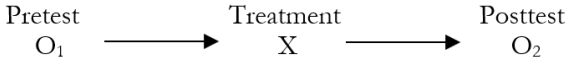

Figure 1. Research Design

Description:
O_1 : Pretest score, to determine the ability of students before being treated
X : Treatment, learning process using POE based e-module
O_2 : Posttest score, to determine the ability of students after being treated

This study was carried out on 33 diverse students at Senior High School 4 Surabaya. The instrument utilized for data collection in this study was a critical thinking skills assessment sheet. The assessment tool utilized for descriptive questions had 11 items related to chemical equilibrium, focusing on the impact of variations in concentration, temperature, pressure, and volume on equilibrium shifts. The critical thinking skills assessment evaluates questions derived from Facione's indicators: interpretation, analysis, inference, explanation, and self-regulation. The questions have been validated by experts.

The methodology for analyzing critical thinking skills involved examining the outcomes from both the pretest and posttest assessments of the students. The pretest measures students' initial proficiency levels, whereas the posttest examines the effectiveness of POE based e-modules. The data regarding critical thinking skills was analyzed through the application of the Paired Sample t-test on the pretest and posttest sheets. The paired Sample t-test requires the data to be normally distributed; therefore, conducting a Normality test is crucial.

4. Results and Discussion

The critical thinking skills test was given to students before learning (pretest) and after learning using POE-based e-modules (posttest). The pretest scores of students showed incomplete criteria, while the posttest scores of students had reached the completion criteria. The pretest average score of critical thinking skills achieved by students is still low, namely 31.19, and the posttest average score is 86.05, with a maximum completeness of 100. This shows a difference in students' pretest and posttest scores, where the posttest score is higher than the pretest score. This difference in score occurs because learning using POE-based e-

modules involves students in predicting a phenomenon, observing through experiments both directly and indirectly, and explaining the suitability of predictions with observations [12]. Then, to find out the completeness of the indicators of critical thinking skills of students is shown in Table 1.

Table 1. Completeness of Critical Thinking Skills of Students

Indicators of Critical Thinking Skills	Pretest	Posttest
Interpretation	37.5	81.3
Analysis	33.3	83.3
Inference	25.0	87.5
Explanation	12.5	87.5
Self-Regulation	75.0	100

The average pretest score showed that students' critical thinking skills were in the incomplete category for the indicators of interpretation, analysis, inference, and explanation. In contrast, the self-regulation indicator had reached the complete category. This shows an increase in student scores from pretest to posttest. The increase in critical thinking skills occurred because students were actively involved in each stage of POE learning, which optimally trained their critical thinking skills. In addition, giving practice questions that contain critical thinking indicators also helps students get used to solving problems related to critical thinking activities [17].

The POE learning strategy encourages active student involvement in the learning process through the stages of prediction, observation, and explanation. This approach not only helps students gain a deeper understanding of concepts but also trains them in critical and scientific thinking [18]. Therefore, the application of the POE model plays a role in stimulating students' critical thinking skills during the learning process. In this study, the indicators of critical thinking skills used include interpretation, analysis, inference, explanation, and self-regulation.

Learning chemical equilibrium using e-modules, the interpretation indicator is poured into the first stage of the POE learning strategy, namely, predict, where an illustration of an experiment is presented, which must be identified as a problem, and a hypothesis is made based on the illustration of the experiment. At the start of the lesson, students are encouraged to make predictions about a phenomenon in order to activate their critical thinking skills [19]. Learning through phenomena is a learning resource that teachers can use to teach students and increase motivation and students' critical thinking skills [20]. It aligns with research by Fitri, which states that POE based worksheets can train students' reasoning and thinking about an event that occurs [21]. Students have been able to understand the phenomena given so that they can analyze the manipulation and control variables, which shows that students can already apply the interpretation indicator [22].

Analysis indicators are outlined in the second stage of the POE learning strategy, namely, observe, where experimental videos and virtual laboratories are presented. Through the experimental video and virtual laboratory, students can find relevant information to solve problems by filling in the observation data table and analyzing the observations that have been made based on the experimental video that has been observed by answering analysis questions. In the observe section, learners make observations about what happens, learners make indirect observations, and learners record what they observe [23].

Inference and explanation indicators are outlined in the third stage of the POE learning strategy, namely, explain. At this stage, students draw conclusions based on the observations made at the observe stage, then compare the results of observations with the initial predictions made at the predict stage. In addition, in the explanation indicator, students are also asked to connect and explain the activities' results with the actual material concepts contained in the reading material, using their understanding. This aims to enable learners to build a deeper and more meaningful understanding. Through discussion activities, learners not only receive information from others but must also build their knowledge by linking information obtained through observation activities [12]. Learners actively participate in discussions and question and answer regarding the phenomenon of chemical equilibrium in everyday life. In the Merdeka Curriculum, classroom learning is required to realize student-centered learning [24].

Self-regulation indicators are outlined on the self-assessment sheet in the developed e-module, where students answer questions related to self-reflection. Self-regulation can be

trained to complete tasks or solve problems that encourage students to achieve learning goals [25]. Learners become more reflective and systematic in evaluating the results of observations, connecting them with theory, and correcting errors that arise in the thinking process. In other words, learners not only perform critical thinking activities but can also monitor their thinking process. Self-regulation skills include managing time effectively and setting achievable goals [26].

The implementation of POE-based chemistry learning modules on chemical equilibrium topics influences students' critical thinking outcomes, as the learning process encourages them to construct their understanding actively. The increased student engagement during lessons with POE-based e-modules aligns with constructivist theory, which emphasizes the importance of students actively participating in building their knowledge [27]. Through the POE learning strategy, students are guided to gain personal learning experiences by collaborating, sharing knowledge, and supporting one another. They are also encouraged to express their ideas in response to prompts from both the teacher and their peers [28].

The improvement in students' critical thinking skills, as reflected in the pretest and posttest results from two groups, was analyzed using the Paired Sample t-Test with the help of the Minitab application. Prior to performing the Paired Sample t-Test, a normality test was carried out as a prerequisite to determine whether the pretest and posttest data followed a normal distribution. This study employed the Ryan-Joiner normality test, which is comparable to the Shapiro-Wilk test and suitable for small sample scale (<50 data points) [29]. If the p-value > 0.05, it indicates that the data are normally distributed and meet the normality assumption. If the p-value < 0.05, it suggests that the data are not normally distributed and the normality assumption is violated. The results of the normality test are presented in Table 2.

Table 2. Pretest Posttest Normality Test Results Critical Thinking Skills

	Mean	StDev	N	RJ	P-Value
Pretest	31.19	11.57	33	0.362	0.423
Posttest	86.05	6.453	33	0.274	0.643

Referring to Table 2, the p-value for the pretest is 0.423, and for the posttest, it is 0.643. Since both p-values are greater than 0.05, it can be concluded that the data from the pretest and posttest are normally distributed, indicating that the assumption of normality has been satisfied. With the normality assumption met, the Paired Sample t-Test can be appropriately applied.

The Paired Sample t-Test is employed to evaluate the hypothesis regarding the improvement in critical thinking skills following the use of POE based e-modules. Additionally, it is used to assess the significance of the difference between pretest and posttest scores. In this study, the Paired Sample t-Test was conducted using the Minitab program and is a one-tail test with a positive trend, which in this case determines whether the paired mean difference between sample 1 and sample 2 is greater than the hypothesized difference. The hypothesis used is as follows.

H_0 : $\mu \leq \mu_0$ The posttest score after using the e-module is smaller than or equal to the pretest score before using the POE based e-module to improve critical thinking skills on chemical equilibrium material.

H_1 : $\mu > \mu_0$ The posttest score after using the e-module is greater than the pretest score before using the POE based e-module to improve critical thinking skills on chemical equilibrium material.

The decision-making criteria are based on the p-value < 0.05; then H_0 is rejected and H_1 is accepted; conversely, if the p-value> 0.05, then H_0 is accepted and H_1 is rejected. The conclusion is drawn accordingly based on the test results. The results obtained through the Paired Sample t-Test test through the Minitab program are presented in Table 3.

Table 3. Paired Sample t-Test Results

Descriptive Statistics				
Sample	**N**	**Mean**	**StDev**	**SE Mean**
Posttest	33	31.19	11.57	2.01
Pretest	33	86.05	6.45	1.12

Estimation for Paired Difference			
Mean	**StDev**	**SE Mean**	**95% Cl for μ_difference**
-54.86	10.37	1.81	(-58.54, -51.18)

μ_difference: mean of (Pretest – Posttest)

Test	
Null hypothesis	H_0: μ_difference = 0
Alternative hypothesis	H_1: μ_difference ≠ 0

T-Value	P-Value
-30.38	0.000

Based on the previous data analysis, the obtained P-value is 0.000, which means <0.05. Therefore, H_0 is rejected and H_1 is accepted, indicating that the posttest scores after using the POE-based e-module are significantly higher than the pretest scores. This suggests that the developed POE based e-module is effective in enhancing critical thinking skills in the topic of chemical equilibrium. According to the results of the Paired Sample t-Test, the average pretest score of 28.2 increased to 85.18 in the posttest, demonstrating a substantial improvement in students' critical thinking abilities after using the e-module. Implementing the POE strategy in the learning process has been shown to improve students' understanding and critical thinking skills [30]. Applying the POE learning strategy can help learners stimulate critical thinking skills during the learning process [31].

6. Conclusions

The results of the study show that POE based e-modules are effective for improving students' critical thinking skills in the topic of chemical equilibrium. This effectiveness is evidenced by the achievement of all five critical thinking indicators after instruction, as well as by higher posttest scores compared to pretest scores, indicating an improvement in students' critical thinking skills. This can be seen from the average pretest score of 31.19 in the poor category, increasing to the posttest score of 86.05 in the good category. The results of the Paired Sample t-Test show a p-value of 0.000 (<0.05), so the decision taken is H_0 rejected and H_1 accepted. Therefore, there is a significant difference in critical thinking skills before and after the implementation of POE based e-modules in learning chemical equilibrium.

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