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The Effectiveness of the Predict-Observe-Explain (POE) Model in The Physics Electronic Modules to Improve Critical Thinking Skills

Honesty Hidayah Nur Permatasari[1*], Suharno[1], Risa Suryana[2]

[1] Department of Physics Education, Faculty of Teacher Training and Education, Universitas Sebelas Maret, Surakarta, Indonesia.
[2] Department of Physics, Faculty of Science and Mathematics, Universitas Sebelas Maret, Surakarta, Indonesia.

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Corresponding Author:
Honesty Hidayah Nur Permatasari
honestytata.s2@student.uns.ac.id

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Abstract: A module is a learning media that is arranged systematically so that it is easy for students to use when receiving material taught by the teacher. Learning in schools using information technology is still not optimal, so it is necessary to develop electronic modules. Moreover, Indonesian students have low critical thinking skills. This study aims to create electronic modules that effectively improve students' critical thinking skills. The method applied is Research and Development. The effectiveness of the developed electronic module can be determined by carrying out the N-gain test, which is obtained from evaluating students' skills before and after using the generated module. The Kolmogorov-Smirnov normality test shows a significance score of 0.000 on the pre-test and post-test, which means that it is not normally distributed, so it is continued with the Wilcoxon test. The Asymp.Sig (2-tailed) of the Wilcoxon test is 0.000, meaning there is a difference between the scores before and after implementing the developed module. The average score of N-gain in the critical thinking skill variable is classified as a high category, namely 0.73. Conclusions are drawn regarding using the Predict-Observe-Explain (POE) model in electronic modules that can improve critical thinking skills, proven effective in learning physics.

Keywords: critical thinking skills; physics electronics module; POE model

Introduction

The value of character education can be inserted into the learning process, including in learning physics (Ananda & Aziz, 2019). Physics explains various physical phenomena that occur in nature, both theoretically and computationally. Physics is a scientific discipline that aims to provide education so that students can find solutions to problems by thinking higher in all aspects and life, so Physics needs to be studied and applied (Dari & Suzima, 2019). Physics is a natural science based on experiments (Prabowo & Sucahyo, 2018). Science education has the main goal of forming students who think like scientists, who are independent, and capable of efficient lifelong learning (Kwarikunda et al., 2022).

Teaching materials support the success of the educational process in schools, one of which is the module. Modules are defined as teaching materials in a language that students understand. They are coherently arranged so that students can learn on their own with the help or guidance of an instructor (Puspitasari, 2019). The purpose of doing the module is so students more easily understand the subject matter the teacher explains. Two types of modules have been developed in education: electronic and printed. The current information era helps us apply knowledge because it is built on digital technology (Alkhabra et al., 2023). One of the ways that teachers can try to face global challenges is by developing modules realized in digital form (e-modules or electronic modules) (Nujuah & Winiarti, 2020).

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Electronic modules are printed modules that are packaged into a digital version so that they are easily accessed using electronic devices and are designed with the help of software (Wiyoko, 2014). E-modules and learning media are urgently needed because schools' current learning process only uses teaching materials such as printed books. The media used are only blackboards, power points, and teaching materials obtained in draft-assisted electronic learning modules (Oktaviana & Putri, 2020). Textbooks published by the government are very general in nature and their contents are not specific to certain fields because they are prepared for use by schools throughout Indonesia (Rohmah et al., 2017). Learning media is able to have a positive psychological influence, increase interest, stimulate learning activities, and raise student motivation (Arsyad, 2014). Learning outcomes, learning motivation, and students' critical thinking skills are very effectively improved using electronic modules (Puspitasari, 2019).

In recent times, sophisticated technology has offered educators the opportunity to explore and create more sophisticated guided learning environments (Hong et al., 2019; Al Mamun & Lawrie, 2023). Internet usage can enhance student interest by presenting well-designed instructional messages that support cognitive development (Hong et al., 2013). To meet educational demands, it is necessary to develop digital learning using technology to increase the effectiveness of students; knowledge and skills. In the era of rapid development of information technology, the learning process can be maximized by developing technology-based learning (Riyanto et al., 2020). Teachers must be able to master technology and computer devices so that students find learning in class very enjoyable (Nurmasyitah et al., 2023).

E-modules are superior to printed modules and are the result of ICT-based module innovation (Cynthia et al., 2023). In the e-module there are materials, images in the form of animations, methods, evaluations, graphics and learning videos. E-modules can be accessed and studied via electronic media anywhere and anytime. E-module development makes it easier for students to understand the material because the learning process is not just textbook-style (Erdi & Padwa, 2021). The advantage of using electronic modules rather than printed modules is that they can be connected to the internet, play learning videos and view animations, so they are effective in increasing learning motivation, increasing students' knowledge and critical thinking skills (Puspitasari, 2019). Interactive and student-centered learning can be created because the learning process of students using electronic modules no longer depends on the teacher as a learning resource. Electronic modules do not need to be printed like books so they can save paper usage (Ghaliyah et al., 2015).

The development of science and technology has had many positive impacts, including education and information systems which have provided various conveniences in carrying out human life activities. Students are involved, concerned, and responsible for the effects of scientific and technological development. Students must know scientific expertise skills, critical thinking, and higher-order thinking (Jamaluddin et al., 2019).

In the twenty-first century, the measure of student success is their cognitive ability because this is reliable and beyond doubt (Aisulu et al., 2023). This generation of students must realize and prepare themselves for a more challenging life. Students must be able to engage in critical thinking to survive in this competitive era (Rehman et al., 2023). Improving the quality of education is one of the basic efforts that can be done (Cynthia et al., 2023). Education in the 21st century integrates knowledge, skills and attitudes as well as mastery of information and communication technology (ICT). So there are four skills that must be processed, namely "critical thinking and problem solving", "creativity and innovation", "communication" and "collaboration" often referred to as "the 4Cs" (Rushiana et al., 2023).

Critical thinking skills are an activity to systematically analyze and evaluate a problem faced according to their beliefs and opinions (Firdaus et al., 2019). Critical thinking requires inductive thinking skills such as identifying interrelationships, evaluating complex problems (with many solution options), establishing root causes and consequences, and concluding and considering relevant data (Rachmantika & Wardono, 2019). It requires increased critical thinking to make decisions, collect various options, formulate conclusions, and solve problems by utilizing all these abilities effectively in appropriate situations (Prameswari et al., 2018). There is reasonable reflective thinking that focuses on deciding what to believe and do (Sato, 2022). According to (Facione, 2020), critical thinking has six aspects: interpretation, analysis, evaluation, inference, explanation, and self-regulation. Critical thinking is broadly defined as the application of cognitive skills and strategies aimed at supporting evidence-based decision making (Bao & Koenig, 2019). In critical thinking, evidence, decisions, decision-making standards, appropriate techniques for forming judgments and theoretical frameworks for understanding existing problems and questions have been carefully considered (Kumar et al., 2023).

Indonesian students' critical thinking skills are considered unsatisfactory. Research by Trends in

International Mathematics and Science Study (TIMSS) conducted to measure students' critical thinking skills through high-level questions showed low results on Indonesian students' critical thinking skills (Nizam dalam Hadi & Novaliyosi, 2019). TIMSS results state that Indonesia consistently ranks low in terms of students' achievement. Indonesia ranked 36th out of 49 countries in 2007, 38th out of 45 in 2011, and 45th out of 50 in 2015. The questions prepared for research in TIMSS are questions that apply high-order thinking skills, including critical thinking, in their completion. Indonesia's low achievement based on the TIMSS study states the low skill of students' critical thinking (Martyanti & Suhartini, 2018).

The 2015 TIMSS results show that data on students with scientific abilities and cognitive domains (understanding, application, and reasoning) are in a low category, namely 54% of Indonesian students. Reason includes higher-order thinking skills, while performance includes critical thinking skills (Gusmawan et al., 2021). The TIMSS study shows low student learning in Indonesia causes low critical thinking skills. Given these conditions, Indonesia needs to inform educators and students that critical thinking skills are required for learning to achieve learning objectives and improve achievement at the international level (Kurniawati & Ekayanti, 2020). Remembering that the teaching and learning process is a focus in the educational context (Muntaner et al., 2020), it is important to recognize pedagogical approaches as an alternative for change (Tirado-Olivares et al., 2023).

The selection of learning models is essential to be applied in class. The learning process makes students learn critical thinking skills and self-confidence. The Predict-Observe-Explain (POE) learning model is suitable (Qomariah & Supardi, 2022). The POE learning model can arouse students' curiosity about the truth of a teacher's concept by proving it through observation or direct observation (Suhaesa et al., 2019). As implied in the constructivist view, learner-centered education usually emphasizes active engagement and inquiry (Bao & Koenig, 2019).

The POE learning model is a series of problem-solving processes carried out by students through 3 main activities (Fitri et al., 2022), namely: (1) Predict: the stage for generating ideas in the form of student predictions about a phenomenon, (2) Observe: the stage of proving the truth of predictions made by student through a direct observation process, and (3) Explain: the stage of explanation to compare the results of observations with initial predictions. The POE model uses three main steps of the scientific method. The advantage of applying the POE model in learning is that it can improve student achievement, increase student's understanding of process skills, increase mastery/knowledge of concepts, increase learning activities, and enhance critical thinking skills (Purdhiyah et al., 2022). It can be said that the POE scientific inquiry model is used to guide students in designing experiments and practical activities with the aim of correcting possible misunderstandings (Wang & Wang, 2023).

Previous research on POE-based electronic modules found that students' critical thinking skills, as measured by an effect size with a score of 3.24, were included in the very high category. POE-based e-modules are effective for achieving predetermined learning competencies (Aulia et al., 2022). Research using POE based e-modules (Aulia & Yuliani, 2021) showed an increase in critical thinking skills with an N-gain score 0.73 and included in the high category. So the conclusion is that the POE model in the e-module can enhance students' critical thinking skills.

Research by applying Physics Worksheets in the POE learning model to improve thinking skills on harmonic vibration material at SMAN 6 Bengkulu City can enhance critical thinking skills based on an N-gain score of 0.57 in the medium category (Ningrum et al., 2022). Learning using PhET simulation has a positive impact on improving students' critical thinking skills, which is marked by increased understanding in analyzing, connecting, synthesizing, predicting, and comparing various problems contained in the simulation (Munif, 2022).

Learning using POE-based worksheets assisted by the PhET Simulation application provided results on the learning scores of class X SMA Muhammadiyah 3 Jember (Istiqomah et al., 2019). The electronic modules for learning physics regarding temperature and heat was declared effective in increasing student learning outcomes at SMA Negeri 15 Palembang (Sari & Siahaan, 2022).

The electronic physics module developed has different characteristics from other teaching materials because this module was created using the POE learning model on Wave Characteristics material and can be used to improve students' critical thinking skills. The physics module developed is packaged in the form of a website/electronic module. This module is equipped with illustrations, learning videos, animations, and interesting experimental simulations with PhET Colorado, so that students understand the material better and do not get bored easily in learning activities.

Based on the program of the less-than-optimal use of technology in learning in schools, this research developed a module that is presented digitally, known as an electronic module, to increase the skill to utilize learning technology. Moreover, the low critical thinking

skills of students in Indonesia need to be addressed. One way is by applying the POE learning model. The development of the physics electronics module is arranged in 3 stages in the POE learning model. This research is expected to examine the effectiveness of electronic modules as teaching materials in improving critical thinking skills.

Method

This research method is Research and Development (R&D) with the aim of expanding knowledge, developing research, and testing the validity of product designed for future education. The product developed is a POE-based electronic module to improve students' critical thinking skills in Wave Characteristics material. The development method used is Analysis, Design, Development, Implementation, Evaluation (ADDIE) which is explained as follows:

Analysis stage

The analysis stage was carried out to analyze the need for developing Physics electronic modules. At this stage, interviews were conducted with the teacher concerned to find out the learning model applied, obstacles in implementing learning, and to find out the need for electronic modules in Physics learning. The availability of modules in schools is also analyzed to improve and develop module content. Analysis of students is also carried out to determine characteristics, cognitive abilities, use of learning media, availability of facilities and infrastructure, and use of electronic devices in learning.

Design stage

Activities at the design stage are identifying and formulating POE-based learning activities, creating ways to improve students' learning outcomes and critical thinking, and designing research instruments.

Development stage

The development stage produces products in the form of electronic modules which are arranged based on the syntax of the POE learning model. This electronic module contains material on Wave Characteristics, equipped with learning activities, pictures, learning videos, animations, PhET Colorado simulations, example questions, and practice questions to increase students' understanding. This electronic module is validated by experts (material, media, and language) and educational practitioners. Validator input and criticism are used to improve the electronic modules being developed.

Implementation stage

Learning activities with electronic modules that have been developed are carried out at the implementation stage. At this stage, a small scale trial was carried out on 18 class XI IPA students to fill out a module readability questionnaire and provide input and criticism for improving the electronic module. The results of the revised electronic module are used to conduct large-scale trials. The research was conducted in January 2023. The subjects in this research were 108 students in class XI Science from SMA Negeri 1 Surakarta, SMA Negeri 5 Surakarta, and SMA Negeri 7 Surakarta. A large-scale trial was used to see students' responses and increase in critical thinking skills after using the POE-based physics electronic module.

This research uses a pre-experimental design with a one group pretest posttest design. The pretest is carried out before students use the electronic module that was developed, while the posttest is carried out after students use the electronic module that was developed. The pretest and posttest in the research were used to compare the conditions before and after using the electronic module to be more accurate. The one group pretest posttest design is explained as follows:

$$O_1 \; X \; O_2 \tag{1}$$

Information:
O_1 = Pretest score (before treatment)
X = Learning using POE-based electronic modules
O_2 = Posttest score (after treatment)

Research calculated the N-gain score after completing the pretest and posttest activities. The analysis process uses the SPSS Statistics 22 program. The calculation begins with a normality test as a prerequisite test. This research uses the Kolmogorov-Smirnov normality test. Decision making guidelines are determined as follows: Data is not normally distributed if the significance score or probability score is < 0.05. Data is normally distributed if the significance score or probability score is > 0.05. Based on the results of the normality test, proceed with the following test:

Wilcoxon Test

The Wilcoxon test is a non-parametric test on data this is not normally distributed and is used to measure the significance of differences between two groups of paired data on an ordinal scale. The hypothesis proposed is:

H_0 = there is no significant difference between cognitive learning outcomes before and after implementing learning using the developed electronic module.

H_1 = there is a significant difference between cognitive learning outcomes before and after implementing learning using the developed electronic module.

Criteria for making Wilcoxon test decisions: H_0 is rejected if the significance score is < 0.05. H_0 is accepted if the significance score is > 0.05

Paired Sample T-Test

Paired sample T-Test is a t test of two paired samples subjected to different treatments. Proposed hypothesis:

H_0 = there is no significant difference between cognitive learning outcomes before and after implementing learning using the developed electronic module.
H_1 = there is a significant difference between cognitive learning outcomes before and after implementing learning using the developed electronic module.

Criteria for making Wilcoxon test decisions: H_0 is rejected if the significance score is < 0.05. H_0 is accepted if the significance score is > 0.05. After carrying out the prerequisite tests, a normalized gain test is carried out. The N-gain score is used to determine whether there is an increase or decrease in student learning outcomes, so that it can be used to determine the effectiveness of implementing POE-based electronic modules to improve critical thinking skills. The N-gain score can be calculated using the formula:

$$g = \frac{s_{post} - s_{pre}}{s_{max} - s_{pre}} \quad (2)$$

Information:
g = N-gain score
s_{post} = Posttest score (final test)
s_{pre} = Pretest score (initial test)
s_{max} = Maximum value

Table 1. Normalized gain criterion

Normalized gain score	Information
$-1.00 \leq g < 0.00$	There was decline
$g = 0.00$	No increase occured
$0.00 < g < 0.30$	Low
$0.30 \leq g < 0.70$	Currently
$0.70 \leq g \leq 1.00$	Tall

(Sundayana, 2016)

The interpretation categories of N-gain effectiveness in the form of percent (%) are presented in Table 2.

Table 2. Categories of interpretation of N-gain effectiveness

Percentage (%)	Interpretation
> 76	Effective
56 - 75	Fairly effective
40 - 55	Less effective
< 40	Not effective

(Nasir, 2016)

Evaluation stage

The evaluation stage is used to draw conclusions based on the results of implementing the electronic module. The conclusion is drawn in the form of a decision whether or not the development of electronic modules is effective to improve critical thinking skills.

Result and Discussion

Results

This research uses an electronic module validated by experts and through trials on a small scale. The module validators consist of material, media, and language experts, consisting of two lecturers and three physics teachers. Eighteen students of class XI IPA carried out small-scale trials. In the validation test, the module was declared feasible to be used for large-scale trials. Data on the pre-test and post-test results of the student's critical thinking skills are presented in Table 3.

Table 3. The Results of Student's Critical Thinking Skills

Test Type	Number of Students	Minimum Score	Maximum Score	Average
Pre-test	108	40.00	83.33	60.12
Post-test	108	63.33	100.00	88.27

Table 4 shows the test results from the analysis of critical thinking skills.

Table 4. The Results of The Analysis of The Pre-test and Post-test Scores of Critical Thinking Skills

Test	Test Type	Significance	Decision
Normality	Kolmogorov-Smirnov	Pre-test = 0.000 Post-test = 0.000	H_0 rejected
The Difference in Pre-test and Post-test Results	Wilcoxon	Asymp. Sig. (2-tailed) = 0.000	H_0 rejected, and H_1 was accepted

The acquisition of the N-gain score is 0.73, with an N-gain percentage of 72.89%. Then, every aspect of the student's critical thinking skills will be analyzed and presented in Table 5.

Table 5. The Average Results of Improving Aspects of Critical Thinking Skills

Aspects of Critical Thinking Skills	Average N-Gain	Category
Interpretation	0.94	High
Analysis	0.84	High
Evaluation	0.63	Medium
Inference	0.71	High
Explanation	0.58	Medium
Self-Regulation	0.79	High

The physics electronics module that has been developed has gone through a validation process and has been improved following the suggestions of the validator. This electronic module is declared fit for use, and its effectiveness has been tested through pre-test and post-test. Students do a pre-test before participating in learning activities with POE-based physics electronic modules. Students do a post-test after participating in learning activities with POE-based physics electronic modules. The test results scores are used to see positive changes in students' score from the research variables, namely critical thinking skills.

Discussion

The results of a large-scale trial on the critical thinking skills tests carried out by students can be seen in Table 1. The average score before the test is 60.12, while the average score after the test is 88.27. This means there are additional results after the test compared to the results before. Before determining the N-gain score, the data is processed as a normality test using the Kolmogorov-Smirnov prerequisite test. The significance score before and after the test is 0.000, as shown in Table 2.

In conclusion, the critical thinking skill data is not normally distributed because H_0 is rejected. Then proceed with the Wilcoxon test for the subsequent analysis stage with an Asymptotic Significance (2-tailed) result of 0.000. The decision taken is to reject H_0 and accept H_1. This means there are differences in the results before and after the test.

Table 3 explains that every aspect of critical thinking skills has increased learning outcomes. The Interpretation aspect has the highest N-gain of 0.94 in the high category. In contrast, the explanation aspect is the score with the lowest average N-gain of 0.58. The conclusion is the overall N-gain average score of 0.73 in the high category. The percentage of the N-gain score is 72.89%. This score is interpreted as quite effective.

There are several previous studies regarding learning with the POE model. Research on learning physics based on POE to train students' critical thinking skills on harmonic vibration material with a percentage of 90% is categorized as very good (Sari et al., 2022). The learning process for high school students to train critical thinking skills using the POE model was declared efficient with an N-gain test score of 0.52 which is included in the moderate classification (Qomariah & Supardi, 2022). Research conducted by Anggraini et al. (2023), influenced students' critical thinking skills in learning the POE model with the STEAM approach. The POE learning model can positively influence the final score of a high school student's critical thinking skills (Okta Nurfiyani et al., 2019). The results of using STEAM-POE based science e-books which convey local wisdom in the form of gamelan show a very good category with a score of 3.266 for students' love of local culture (Setianingrum et al., 2023). POE learning is able to bring positive changes to students' understanding of concepts and can improve cooperative skills (Papilaya & Tuapattinaya, 2022). Students can make reasonable predictions after applying the POE strategy in conducting research (Kala et al., 2013).

It can be concluded that there is an increasing in the results of calculating the N-gain score for the research variables after students use the POE-based physics module compared to before using developed module. The learning activities that students get through the stages of the POE model are associated with aspects of critical thinking. The electronic physics module developed to support the learning process is integrated with learning media. This module has illustrations, videos, animations, and practicum activities using PhET simulations, samples, and practice questions. Modules that experts and physics teachers have validated are declared feasible and are expected to be used to assist students' learning processes.

Conclusion

The research that has been done is an attempt to develop an electronic physics module that is expected to be used effectively in learning physics. The electronic module is arranged with the stages of the POE model. The draft module underwent an assessment process by experts and small-scale trials by students and was revised according to the comments and suggestions given until it was declared capable of use. The developed electronic modules are said to improve critical thinking skills effectively. The increase in students' critical thinking skills was categorized as high. The suggestion that the researcher gives to further researchers is that POE-based electronic modules can be developed to assess other variables and other physics materials. POE-based electronic modules are also expected to be applied in class as better teaching materials by teachers.

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