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# Effect of PDEODE-STEM Learning on Students' Critical Thinking Ability on Work and energy Topics

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## ABSTRACT

This study aims to see the effectiveness of the implementation of PDEODE-STEM in improving students' critical thinking ability. The study was conducted at SMAN 8 Malang, with a sample of 108 students divided into three classes with a total of 36 students in each class. To achieve this goal 10 essay questions were designed based on indicators of critical thinking. Data analysis was performed with one-way ANOVA test with post hoc test, effect size and N-gain. The results showed that in the three classes there were significant differences in pretest-posttest critical thinking ability. However, classes taught with PDEODE-STEM are better than PDEODE and conventional.

**Keywords:** Critical thinking, PDEODE-STEM learning, ability,

## INTRODUCTION

One of the goals of learning physics is so that students have a deep and comprehensive understanding of concepts. Deep understanding of concepts is very useful to help students solve the problems and explain the various physical phenomena [1]–[5]. One of the fundamental topics that students must understand is work and energy [6], [7]. The concept of work and energy is closely related to everyday phenomena [8].

However, the findings show that many students have many difficulties to understanding the concepts of work and energy, such as difficulties in understanding the system [9]; applying the law of conservation of mechanical energy, determining the relations of work and displacement, and applying the concepts of work and energy in everyday life [10]; difficulty in correlating the concept of energy with other subjects [11], etc. Difficulties of students in understanding the concept causes low critical thinking ability of students. Based on the results of the study, students' understanding of concepts correlates significantly with critical thinking ability [12]. Though critical thinking is an important aspect that students must have in the 21st century [13]–[15]. So in science learning students must be directed to have critical thinking ability.

Students' critical thinking ability can be improved by applying well-planned learning. One of the lessons that can improve students' critical thinking ability is constructivist learning. Predict-Discuss-Explain-Observe-Observe-Discuss-Explain (PDEODE) is one of learning model with constructivist principles. The implementation of PDEODE can help students understand everyday phenomena, make learning more meaningful, and make students the center of learning [16]. In PDEODE learning students are facilitated to discuss. Discussion learning can improve critical thinking ability effectively [17]. Each stage in PDEODE learning trains students to observe phenomena, to make predictions, to prove and conclude the predictions. These stages can facilitate students to practice critical thinking ability.
In addition to using learning models, there is way to improve students critical thinking, namely Science, Technology, Engineering and Mathematics (STEM) education [18]. The goals of STEM are the same as the goals of the 21st century education so that students are able to solve problems, make decisions, analyze assumptions and develop knowledge to be applied in daily life. STEM is able to create an active learning system because all four aspects are needed simultaneously to solve problems [19], [20]. Although STEM has great opportunities in building students' abilities in various aspects, in Indonesia STEM still has not received special attention by teachers in teaching [21]. Especially research by implementing PDEODE-STEM learning is still very rarely done in Indonesia. Therefore, this research will focus on exploring the effectiveness of STEM integrated PDEODE implementation to improve students' critical thinking ability.

## RESEARCH METHOD

This study uses a quasi-experimental research with pretest-posttest design [22]. The study was conducted on 108 grade X students of SMA Negeri 8 Malang, East Java, Indonesia. There are 3 classes with 36 students in each class. The class is an experimental class I, an experimental class II, and a control class. Students in the experimental class I were taught using PDEODE-STEM, students in the experimental class II were taught using PDEODE, and students in the control class were taught using conventional learning methods.

PDEODE learning is carried out through 6 stages namely, predict, discuss, explain, observe, discuss, and explain [23]. Learning in PDEODE-STEM classes is done by integrating several STEM components, namely Science, Technology, Engineering, and / or Mathematics in PDEODE learning. STEM is integrative so it can be integrated into various learning models. STEM integration in PDEODE learning such as, (1) at the predicting stage, the scientific aspects are used by students in predicting phenomena using their knowledge; (2) at the discussion stage, technological aspects are used when students are allowed to look for solutions to problems using the internet and aspects of matematics are used by students by formulating solutions to the phenomena presented by the teacher; (3) at the observe stage, technological aspects are used when students design experimental sets to prove predictions and engineering aspects are used when students are required to be creative in designing experimental sets.

Data obtained from pretest-posttest using 10 essay questions. The questions given have fulfilled the test instrument criteria, which are valid and reliable. The questions are designed according to the critical thinking indocator developed by Ennis. Data on the critical thinking ability scores of students were analyzed using one-way ANOVA with post hoc tests, effect size and N-gain.

## RESULTS AND DISCUSSION

In the first part of the research results, we describe the results of descriptive statistical analysis. Descriptive statistics of the pretest-posttest data as shown in Table 1.

**Table 1.** Descriptive Statistics of Pretest-Posttest Data

| | Class | Mean | Standar Deviation | Skewness |
|---|---|---|---|---|
| **Pretest** | Eksperiment Class I | 30.47 | 8.49 | -0.19 |
| | Eksperiment Class II | 31.14 | 7.24 | 0,08 |
| | Control Class | 30.68 | 7.01 | -0.22 |
| **Posttest** | Eksperiment Class I | 64.37 | 7.56 | 0.10 |
| | Eksperiment Class II | 57.93 | 9.17 | 0,24 |
| | Control Class | 44.68 | 8.43 | -0,16 |

Based on the data in Table 1, we can see that the average score of students in all classes shows an increase. The average score of students in the experimental class I increased from 30.47 to 64.37, experimental class II increased from 31.14 to 57.93, and the control class increased from 30.68 to 44.68. Based on these data it appears that the skewness value for each data group is in the range -1 to +1. This indicates that all data in each class is normally distributed [24].

In research with quasi-experimental designs, it is important to see that the whole class has relatively similar characteristics. It's useful to reinforce the claim that increasing of scores in each class is not influenced by the characteristics of students and all classes began with the same conditions. Table 2 shows the results of the one-way ANOVA test for the different tests for each group of data.

**Table 2.** One-Way ANOVA Test

| | Source | Sig. | Alpha | Conclusion |
|---|---|---|---|---|
| **Pretest** | Between-group | 0.437 | 0.05 | No difference |
| **Posttest** | Between-group | 0.000 | 0.05 | Difference |

Based on the data in Table 2, we can conclude that the critical thinking ability of students in each class are not significantly different. This shows that the initial ability of all class groups is relatively no different, so it can be said that the increase in students' critical thinking ability in each class is not influenced by initial abilities. On the other hand, based on the results of the one-way ANOVA test, it can be concluded that the students' critical thinking ability in each class after learning have significant differences. This is indicated by the value of sig. < 0.05. For this reason, further tests are needed to see the difference in students' critical thinking ability in each class. In this study the Post Hoc Test was used. Post Hoc test results as shown in Table 3.

**Table 3.** Post Hoc Tukey Test Result For Posttest Data

| Between Classes | Statistic Test | Sig. | Alpha | Conclusion |
|---|---|---|---|---|
| PDEODE-STEM and PDEODE | Post Hoc Tukey | 0.018 | 0.05 | Difference |
| PDEODE-STEM and Conventional | Post Hoc Tukey | 0.000 | 0.05 | Difference |
| PDEODE and Conventional | Post Hoc Tukey | 0.000 | 0.05 | Difference |

Based on the data in Table 3, we can conclude that the critical thinking abilities of students in each class are significantly different. This is evident from the value of sig. < 0.05. For further, the difference will be more meaningful if the increase is known. N-gain values and categories for each class as shown in Table 4.

**Table 4.** N-gain Value for Each Class

| Parameter | N-Gain | | |
|---|---|---|---|
| | Experiment Class I | Experiment Class II | Control Class |
| **N-Gain** | 0.49 | 0.39 | 0.20 |
| **Category** | Medium | Medium | Low |

N-gain values in the experimental class I and experiment II are in the medium category while the control class is in the low category. These results indicate the positive impact of an increase in students' critical thinking ability after learning by using PDEODE. The improvement of students 'critical thinking ability is in accordance with the results of Diani's study which states that learning with PDEODE * E task can improve students' critical thinking ability [25]. Furthermore, to see how strong the effect of learning that is implemented in each class, the calculation of d-effect size is needed. The results of the calculation of d-effect size as shown in Table 5.

**Table 5.** d-Effect Size Value for Each Class

| Parameter | N-Gain | | |
|---|---|---|---|
| | Experiment Class I | Experiment Class II | Control Class |
| **d-effect size** | 4.22 | 3.27 | 1.81 |
| **Category** | Very high | Very high | Very high |

The effect of PDEODE-STEM, PDEODE, and conventional learning is very large on improving students' critical thinking ability. This is indicated by the value of the d-effect size obtained. Based on Table 5, all classes have d-effect size values in the very high category. Based on the research results obtained, PDEODE learning will be more effective in improving students' critical thinking ability compared to conventional learning. It would be better if integrating STEM into learning PDEODE.

It has been found that learning with a constructivist approach is useful in practicing students' thinking ability With constructivist learning students will be actively involved in building their knowledge. Students not only receive knowledge from the teacher passively. PDEODE which is a constructivist learning is also useful in improving students' thinking ability, including critical thinking ability. Not only students critical thinking ability, the application of PDEODE is also able to increase student motivation [26]–[28]. On the other hand, if students' motivation is high, it will positively influence their critical thinking ability.

These results reinforce the results of this study, where students seem more excited when learning with PDEODE learning compared to conventional learning. Students are more actively involved in learning.

On the other hand, the use of STEM in learning can also effectively improve students' critical thinking ability [29], [30]. learning by integrating STEM can facilitate students to think higher-level through problem solving challenges or phenomena. STEM can provide authentic, practical and meaningful learning experiences [31]. In addition, learning in the future requires the professional development of teachers to prepare students for the world of student work later so it needs to be applied STEM [32]. Therefore, habituation of students to learn better is important, not just being a recipient of information from the teacher.

## CONCLUSIONS

The results showed that there was an increase in students' critical thinking ability in all classes, both taught with PDEODE-STEM, PDEODE, and conventional. Based on the results of the one-way ANOVA test, it can be concluded that the critical thinking abilities of students after learning differ significantly. The N-gain results in the experimental class I are 0.49 (medium), experimental class II is 0.39 (medium), and the control class is 0.20 (low). Finally, the impact of learning on all three classes is very high as indicated by the value of d-effect size. Overall it can be concluded that the learning of PDEODE-STEM is better than PDEODE and conventional to improve critical thinking ability.

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