The Effectiveness Of Problem-Based Interactive Physics E-Module On High School Students’ Critical Thinking

Rai Sujanem¹, I Nyoman Putu Suwindra², Iwan Suswandi³

¹,²,³ Study Program of Physics Education, Faculty of Mathematics and Natural Science, Ganesha University of Education

Email: rai_sujanem@undiksha.ac.id

Abstract. This study aimed at analyzing the effectiveness of an interactive physics e-module (IPEM) to improve students’ critical thinking skill (CTS). IPEM is a module that contains unstructured problems, physics phenomena in the form of animations, videos, examples, and CTS problems. This IPEM was presented in the blended problem-based learning (BPBL) model. The population consisted of all tenth grade students at SMAN 2 and SMAN 4 Singaraja and classes X1 and X4 in SMAN 2 Singaraja and SMAN 4 Singaraja were selected as the sample by using a random sampling technique. The study used a quasi-experiment one group pre-test and post-test design. Before the lesson was taught by using IPEM, the students were given a CTS pretest. At the end of the lesson, they were given the same test (post-test). The data were analyzed using a paired t-test. The results showed that the average students’ CTS before using IPEM was 22.7, falling into a poor category, and the results showed that the average students’ CTS before using IPEM was 59.1, falling into a medium category. The using a paired t-test result shows that there is a significant difference in the students’ CTS before and after using the IPEM. The students’ CTS after using IPEM is better than before using IPEM in learning process. That is why the IPEM in the BPBL model is effective to improve the students’ CTS of high schools.

1. Introduction

This globalization era requires education that provides competencies that meet the need of the society. Based on the studies in various fields such as social sciences, it is known that students who have graduated from schools in various countries do not have the ability to compete at the global scale since they do not have the ability to think critically [1]. The importance of critical thinking actually has been proven since the era of Socrates. The inability of the output of teaching to think critically has become the national issue that has to be overcome soon [2].
Critical thinking skill (CTS) is one of the pillars of the 21st century paradigm [3]. CTS is one of the systematic processes when the students make decisions about what that they are thinking and doing [4]. Physics is one of the means to develop thinking abilities that are useful for overcoming problems in daily life [5]. CTS is important as what the curriculum states and can be used as the reference in the teaching process to attain an expected learning achievement. According to Semerci [6], the students who have a higher CTS have a higher learning achievement than those with a lower CTS. CTS is the key in education to solve a problem. Most of jobs require human resources with the ability to use CTS [7]. By knowing how important CTS is, it is just fitting that the teaching process always emphasizes the importance of the students’ CTS. However, it is very ironical that the teaching of thinking at schools at this moment, especially at senior high school has not been carried out well so that the CTS of senior high school students is still relatively low. The low CTS and creativity of the graduates of schools, from elementary to college level in Indonesia is still a problem that people often complain about [8]. There are several things that cause the students’ CTS low (formulating the problem, giving the argumentation, analyzing inductively, analyzing deductively, and making a decision) that cause the low students’ CTS, which include the types of problems with a low Bloom’s taxonomy levels that do not train the students to think [9, 10]. The CTS of the students in Bali is still low [11, 12]. The quality of physics teaching as part of science education up to now has been low and undergone a decrease as shown in the study by PISA (Program for International Student Assessment), a study focusing on reading literacy, mathematics, and science that shows that Indonesia ranks 64th out of 72 countries [13]. This shows that the quality of sciences education in Indonesia is still low [11,12, 13]. The quality of physics education is also seen from the still low CTS. The result of a study done by [11] in some regencies in Bali shows that that the mean score of the CTS of the tenth grade students of senior high school was 49.38 from the 100 point scale. The result of the preliminary study of the CTS test on physics materials done at public senior high schools in Singaraja to the students who had studied the momentum and harmonic vibration topics was low and the mean score was low and the result of a CTS test of the eleventh grade students of MIA 1 was 40.2. For SMAN 3, SMAN 4 and SMAN 1 Singaraja, the mean scores in CTS of the eleventh grade students of the XI MIPA ranged from 38.50 to 43.2 with a low category [12] The result of the students’ CTS was still low, while on the other hand it is very important to train and develop the students’ CTS. CTS is the key in education to solve a problem. The result of the students’ CTS was still low while it needs to be trained and developed in education. There are several things that cause the students’ CTS low hence low of CTS in physics teaching is also expressed by Zuryanty et al. (2019) [14].

The main cause of the discrepancy is the fact that physics teaching at school still uses lecturing method, the students only receive information and they are faced with the problems presented in figure and computation. Physics problems are not designed by considering the relation between them and the daily phenomena. The low achievement of the students’ CTS occurs because so far the presentation of education does not go parallel to the nature of physics learning and teaching [15]. For this reason there is a need to design education that runs parallel to the nature of the teaching and learning, that is, how the students learn, how the teacher teaches, how the message in the teaching in the teaching materials, not only in the learning achievement [15]. The existing physics teaching materials so far have been in the form of textbook, module, and students’ worksheet. The presentation of senior high school physics teaching materials is still linear, i.e.: the teaching materials only present concepts and principles, examples of problems and their solutions, and practice problems. The presentation of physics teaching materials (textbook, module and its implementation) has not given any opportunity to train the students’ CTS, such as the practice in stating problems, analyzing inductively and deductively, giving argumentations and
making decisions. In addition, together with the development of TIK, the teaching materials so far available has not yet been presented in electronic books (e-book) or electronic modules (e-module).

Based on the explanation above, there is a need to design teaching materials in the form of e-module for physics based on problems. This problem-based physics is oriented toward the provision of opportunity to the students in achieving CTS at senior high school. Problem-based interactive physics e-module (IPEM) was presented in a blended problem-based learning (BPBL) of face to face and online model. The BPBL model of combination (blended) learning is the combination between the face-to-face PBL and online [16, 17, 18, 19] The face-to-face PBL model presents problems as stimuli to learn face to face. The problems are presented in a very complex and unstructured way and are related to the students’ world [20, 21, 22, 23]. There are PBL models that only use the classroom face to face system. This kind of face to face PBL model is often called the traditional PBL model. This PBL model is often used to enhance the students’ achievement. However, this face to face PBL model has limitations, so that this face to face PBL is combined with online learning known as blended PBL (BPBL). In the implementation this BPBL learning model was used with an IPEM. The theoretical foundation that supports the use of an IPEM in this BPBL model is the constructivist learning theory, blended learning, PBL, meaningful learning, Vygotsky’s learning theory, Albert Bandura’s learning theory and online learning theory. Meaning is created by the students from what they see, hear, and experience. Blended learning model is used as the basis for designing the model and this comes from the idea that learning is basically a social process that will be compromised directly with the virtual world that is far from human interactions. This kind of face to face PBL model is often called the traditional PBL model. This PBL model is often used to enhance the students’ achievement. However, this face to face PBL model has limitations, so that this face to face PBL is combined with online learning known as blended PBL (BPBL). In the implementation this BPBL learning model was used with an IPEM. The theoretical foundation that supports the use of an IPEM in this BPBL model is the constructivist learning theory, blended learning, PBL, meaningful learning, Vygotsky’s learning theory, Albert Bandura’s learning theory and online learning theory. Meaning is created by the students from what they see, hear, and experience. Blended learning model is used as the basis for designing the model and this comes from the idea that learning is basically a social process that will be compromised directly with the virtual world that is far from human interactions.

The integration of ICT into the world of education, especially blended-based learning brings out a new revolution and gives opportunity to attain CTS and a higher learning achievement (IHLP, dalam Oliver, 2003 [24, 25]. Through the implementation of the online PBL, the CTS of the students in physics increases [26]. The CTS is higher after being given teaching using the PBBL model [27]. The PBL that is designed in the website is presented with information, picture, map, problem-based teaching plan for teachers. The teacher has to help students using the internet effectively. The internet is a very good source for PBL [20].

The novelty of the presentation of an IPEM that has been developed in the BPBL module in the teaching of senior high school physics is that it contains unstructured problems (ill-structured), physics phenomena, essential and strategic concepts, concepts that have CTS content, CTS problem examples, physics animation/stimulation, video, and CTS problem practices. An interactive physics e-module (IPEM) can be accessed online both at the time of face-to-face teaching or outside the lesson period. The students can access teaching materials through the online system.

The main objective of this study was to find out the effectiveness of e-modul fisiberma to enhance the CTS of the students at SMAN in Singaraja in learning physics. The CTS indicators include formulating problems, giving arguments, doing deductions, doing inductions, and making decisions. The problem in this study can be formulated as: how effective is IPEM in the BPBL model to enhance CTS in teaching physics at senior high schools?
2. Methods
2.1 Study Design

This study stresses the importance of analyzing the effectiveness of an IPEM in the BPBL learning model to enhance the students’ CTS. The study used the pre-experiment pre-test and post-test design [28, 29, 30] with replications as shown in Figure 1.

![Figure 1. The one group pretest and posttest Design](image)

In Figure 1, the symbols $O_1$ and $O_2$ are pre-test and post-test that state that show CTS. X symbolizes an interactive physics e-module (IPEM) treatment in the BPBL model. Before the teaching was conducted using IPEM in the BPBL model, both groups were given a pre-test ($O_1$) and after the teaching was conducted using an IPEM in the BPBL (X), the students were given the same test again or a post-test ($O_2$).

The study was done to the students group of the tenth class in the 2017-2018 academic year at SMAN 2 and SMAN 4 Singaraja with the total number of 59 students. The module was used at every meeting, and the total meeting was 16 times during two months. IPEM is also used by students to study or do assignments outside of class schedules both at school and at home, or anywhere.

2.2 Methods of Data Collection and Data Analysis

The method of data collection used in this study was the test method. The test was used to know an increase in the students’ critical thinking skill from before to after the implementation of an IPEM in the BPBL. The data of CTS were collected by pretest and posttest. Pretest was given before using an IPEM and posttest is given after using an IPEM. The CTS test was in the form of essay, consisting of indicators: (1) formulating problems, (2) giving arguments, (3) reasoning by deduction, (4) reasoning by induction, and (5) making a conclusion.

The data of the CTS test result collected were analyzed using the paired t-test. The paired t-test is done if the data of the population meet the criteria of normal distribution [29, 30, 31, 32]. On the other hand, the computation of the N-gain score was done to analyze the increase in the CTS level as the effect of the implementation of an IPEM in the BPBL model in teaching physics. The mean score of the increase in CTS was determined by normalizing the N-gain. The effectiveness of an interactive physics e-module (IPEM) in the BPBL model was examined based on the paired t-test. The mean of the CTS improvement was determined by the value of the normalization of gain (N-gain) [33]. The N-gain categories according to Hake [33] are (1)”a high gain “, if the N-gain $>0.7$; (2)”a medium gain “, if $0.7$> N-gain $>0.3$; and(3)”a low gain “, if N-gain $<0.3$. Statistical analysis was done aided with the software of IBM SPSS Statistics 25.

In addition to the descriptive analysis that used N-gain, the paired t-test was also used to determine the significance of the increase in critical thinking skill. The data analysis technique use the paired t-test by using the software package of SPSS Statistical Package version 25. Before the researcher used this data analysis technique, there were some requirements that had to be met, namely normality testing [29, 32]. The normality testing used Kolmogorov-Smirnov [32].
In addition to the descriptive analysis that used N-gain, the paired t-test was also used to determine the significance of the increase in critical thinking skill. The data analysis technique used the paired t-test by using the software package of SPSS Statistical Package version 25. Before the researcher used this data analysis technique, there were some requirements that had to be met, namely normality testing [29, 32]. The normality testing used Kolmogorov-Smirnov [32].

3. Results and Discussion

3.1 Results

The result of the CTS test of the students consisted of pre-test and post-test results obtained through a written test in the essay format. The test was given to Class X MIPA 1 of SMAN 2 Singaraja, and Class X MIPA 4 of SMAN 4 Singaraja. The mean scores for the pre-test and post-test can be seen in Table 1.

Table 1. The Description of Pretest and Post-test of Students’ CTS

|                | Pre-test | Post-test |
|----------------|----------|-----------|
| Lowest score   | 15,0     | 39,0      |
| Highest score  | 31,0     | 80,0      |
| Mean           | 22,7     | 59,1      |
| Standard Deviation | 3,77   | 10,52     |
| Ideal Score ideal | 100    | 100       |
| Number of Students | 59    | 59        |

Based on Table 1, it appears that the mean score of the CTS before the teaching (pre-test) for harmonious vibration were 22.7, falling into a very poor category. After the teaching using an IPEM in the BPBL model, the CTS mean (post-test) became 59.1 falling into a medium category. Then, the mean for pre-test, the mean for post-test, and N-gain mean for students’ CTS can be shown in Figure 1.

Figure 2 shows an increase of the students’ CTS. The increase in CTS for the students were categorized as medium as shown by the N-gain scores as shown in Figure 3. The result of the paired t-test between the pre-test and the post-test for the students’ CTS have met the normality criteria as shown in Table 2.
Table 2. The Result of the paired t-test between pre-test and post-test for students’ CTS

| Pair | Data        | Mean     | Std. Deviation | Std. Error | 95% Confidence Interval of the Difference | t   | df | Sig. p(2-tailed) |
|------|-------------|----------|----------------|------------|-----------------------------------------|-----|----|-----------------|
| 1    | Pre_test    | 36.47458 | 7.89883        | 1.02834    | -38.53302 - 58.46                      | 1.02834 | 11 | 0.000           |
|      | Post_test   | 58.53302 | 38.53302       | 35.46      |                                         | 11  | 0.000           |

Table 2 shows that the p value for the t-test of the pre-test and post-test for the students’ CTS was < 0.05 and on the whole had a negative value. This means that there was a significant difference (statistically) in CTS of the students between before and after the use of an IPEM in the BPBL model. The CTS of the students was higher after the use of IPEM in the BPBL model compared to that before the use of an IPEM.

3.2. Discussion

Based on the data of the results of the study, the level of the CTS of the students in pre-test was only 22.7, falling into a poor category, and the level of the CTS of the students after the use of an IPEM reached 59.1 falling into a medium category. Based on the N-gain, the CTS of the students of SMAN 2 Singaraja and SMAN 4 Singaraja there has been a 0.5 increase in the medium category of increase. On the other hand, the CTS of the students has increased significantly. Thus, the implementation of IPEM can be said to be effective to enhance the CTS of the students. This is consistent with the finding of Wannapiroon [27] that the combination learning (blended learning) based on problems can enhance CTS. This is also in agreement with the finding of Sulaiman [26] that online problem-based learning is effective to enhance CTS.

The attainment of the CTS of the students is shown in Figure 1 the mean score in the pre-test of the students before the implementation of an IPEM in the BPBL model fell into a low category, 22.7 from the 100 point scale. After the implementation of IPEM in the BPBL model, the CTS mean scores of both groups of students were higher, 59.1. The low score for the CTS of the students in the condition before the implementation of an IPEM in the BPBL model might have been caused by the fact that the students had not been taught CTS. After the implementation of an IPEM in the BPBL model, their scores became higher. The increase in the mean of CTS of the students is shown in figure 2, significant statistically with α = 5%. In figure 2 it is shown that the N-gain mean scores, fell into a medium category based on Hake’s criterion [33], that is 0.5.

An increase in CTS at this high category might have been caused by the use of an IPEM in the BPBL model, in which the students were trained in the attainment of the CTS indicators at each stage. (1) at the problem orientation stage, the students learned to understand the problem of harmonic fibration as ill-structured problems, and identifying problems based on theories, (2) at the teaching organization stage,
the students formulates complex problems into simple ones based on the phenomena of the momentum and harmonic vibration topics, (3) at the investigation stage, the students gave arguments, gave solutions or suggestions according to the problems or theories (making a decision), reasoning inductively, (4) at the stage of development and presentation of results, the students gave arguments, analyzed deductively, and making a decision (giving a solution or suggestion according to the problems and theories), 5) at the analysis and evaluation process of problem solution, the students gave arguments, analyzed inductively and deductively and made a decision (giving a solution or suggestion based on the problems or theories), (6) at the stage of giving examples of application and doing the CTS problems, the students formulated problems, giving arguments, and analyzing inductively and deductively as well as making a decision (giving a solution or suggestion based on the problems).

In figure 2 it is shown that the increase in the CTS of the students, N-gain for the students’ CTS. This shows that the implementation of the teaching with an IPEM in the BPBL model could enhance the CTS of the students. This is consistent with the schema theory that states that when someone is constructing information, he or she is adapting with his or her previous knowledge that he or she has had in his or her mind [34]. The implementation of an IPEM in the BPBL model is a model for integrating ICT in the education world that can give opportunities for the attainment of a higher CTS. The effect of the implementation of an IPEM in the BPBL model is supported by the finding of Wannapiroon [27] that CTS will be higher after the use of teaching with the BPBL model. Similarly, it is also supported consecutively by the findings of Sulaiman [26] that expresses that the CTS of the students increase in physics through the implementation of PBL online; of Sulaiman and Elnetthra [26, 35] that conclude that PBL online can enhance CTS; Vidic show that PBL significantly increases the students’ competence in planning and organizing learning [36], an IPEM in the BPBL provides hyperlinks so that it makes the students familiar with the teaching materials.

The implementation of IPEM in the BPBL model is a contextual and meaningful learning model for the students of SMAN 2 Singaraja and SMAN 4 Singaraja. This is in line with the schema theory which states that an individual reconstructs information, adapting to his or her previous knowledge that has existed in his or her mind previously [34].

In addition, one of the learning theories stresses the importance of meaningful learning is the constructivist theory that states that the students have to find and transform complex information if he or she wants to become himself or herself, by considering new information from the point of view of the old rules and changes the rules when the rules are no longer useful [37]. Focusing on the constructivist theory, the role of the teacher in teaching is only as facilitator.

The implementation of an IPEM in Physics teaching stresses that the students have to actively develop the knowledge and understanding by themselves. To develop meaningful information that is relevant to the students, the teacher has to give opportunities to the students to find or implement their ideas, and consciously implement their strategies to learn. Hence, the attainment of learning achievement related to the CTS is basically supported by the rational theoretical foundation. Like the pre-test data
shown above the CTS of the students was 22.7 falling into a poor category. This result is consistent with the previous finding in the preliminary study [12], that also showed that the CTS of the students of public senior high schools in Singaraja fell into the poor category too. The finding on the CTS of the students before the teaching using IPEM in the BPBL is contradictive with the use of CTS as expressed by Iakovos [38], that is, critical thinking has an important role in education and is the main objective in learning. Based on the result of data analysis it was obtained that generally, the CTS of the students increased at 0.6. When the N-gain was used, the increase in the CTS of the students was 0.5. According to Hake [33], generally, this falls into a high category. Based on the result of the testing of the mean difference between the pre-test and the post-test using the paired t-test as explained above, it was found out that the use of an IPEM can increase the CTS of the students significantly, $\alpha = 0.05$. Thus, it can be said that the use of an IPEM in the BPBL is effective. This is in agreement with the study done by Wannapiroon [27] that states that the combination learning (blended learning) based on problems can enhance CTS. This is in line with the finding of Sulaiman [26, 35] that states that the online problem based learning is effective in enhancing CTS. This shows that learning through an IPEM in the BPBL model can develop the CTS of the students. In addition, the study by Elnetthra and Sulaiman [35] showed that PBL online can enhance CTS. According to Ennis [10], CTS covers the formulation of problems, giving arguments, reasoning deductively, reasoning inductively, making a decision, and implementing. The integration of ICT in the world of education, especially in relation to the presentation of blended learning based model brings about a new revolution and gives opportunities to attain CTS and a higher learning achievement [24, 25].

4. Conclusion

Based on the results above it, the following conclusions can be made.

1) The use of an IPEM in the BPBL model can enhance effectively the CTS of the students. The increase in the CTS has enhanced N-gain at 0.5, falling into a medium category.

2) Based on the result of the paired t-test it is shown that the CTS of the students of Class X MIPA at SMAN 2 and SMAN 4 in Singaraja has increased significantly with $\alpha = 0.05$ after they got an instruction that used an IPEM in the BPBL model.

3) The students’ responses fell into a very good category to the implementation of IPEM with the BPBL model in Physics teaching.

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