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PROBLEM-BASED INTERACTIVE PHYSICS E-MODULE IN PHYSICS LEARNING THROUGH BLENDED PBL TO ENHANCE STUDENTS' CRITICAL THINKING SKILLS

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ABSTRACT

Problem-based interactive physics e-modules (Probinphys), accessed online, were chosen as an alternative method for enhancing high school students' CTS. This study analyzed the efficacy of the Probinphys E-Module in enhancing high school students' CTS and described student responses toward the Probinphys E-Module through the Blended-Problem Based Learning (blended-PBL) model. The Probinphys e-module was efficient in enhancing CTS if there was a significant enhancement in student CTS and the minimum average N-gain was in the moderate or consistent category. Student responses toward the Probinphys e-module were in the high category. This research applied one group pretest and posttest group design, involving 79 students in three groups from grade eleven. Before and after learning with the Probinphys E-Module, the three groups of students were given the same CTS test. The collected data were analyzed using Paired-Test, normalized gain (N-gain), and ANOVA. The results show that using the Probinphys e-module in blended PBL efficiently enhances students' CTS, as indicated by the average N-gain for the three groups in the high category. The average N-gain is the same at 0.5 for the three groups or consistently. Student response toward the Probinphys e-module in blended-PBL is very high.

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Keywords: blended-PBL; critical thinking skills problem-based interactive physics e-module

INTRODUCTION

The current educational process focuses on teaching students skills and innovations relevant to the 21st century, such as critical thinking, problem-solving, decision-making, creativity, and creative thinking. It also emphasizes teaching students how to collaborate and cooperate and how to use digital information sources (Griffin & Care, 2015; Jatmiko et al., 2018; Sujanem et al., 2020). There are many different ways that critical thinking can be defined and measured, but in most cases, it involves a person's capacity to recognize important relationships and identify central issues and assumptions in arguments (Mason, 2017). According to previous research, critical thinking is a cognitive skill. It includes self-management in problem solving as well as interpretation, analysis, evaluation, inference, and explanation (Siew & Mapeala, 2016; Mundilarto & Ismoyo, 2017).

One of the demands of the 21st century is critical thinking skills. Critical thinking skills are a systematic process when students make decisions about what they believe and do and are one of the goals of education (Ennis, 2015; Sujanem et al., 2018; Sujanem et al., 2020). Students need to be able to think critically in order to be aware of how to develop, monitor, and assess what they have learned, obtain knowledge, and face and solve complicated problems in technology and societal issues, critical thinking skills must be mastered in new settings and problems (Oliveras et al., 2013; Brookfield, 2017; Geçit & Akarsu, 2017; Vong & Kaewurai, 2017; Misbah et al., 2018; Puspitasari,

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2019; Aufa et al., 2021). Indicators of providing decisions also enhance critical thinking skills and produce logical problem-solving and higher thinking speed.

Ironically, thinking skills in schools, especially in high schools, have not been handled well, so high school graduates' critical thinking skills are still relatively low. Many still complain about the low critical and creative thinking skills of graduates from elementary schools to universities in Indonesia. Several factors contribute to students' poor critical thinking skills, including low-level Bloom's taxonomy questions that require no critical thinking (Pursitasari & Permanasari, 2013). Pelawi and Sinulingga (2016) also stated that students prefer to remember concepts and equations, and they lack a natural phenomenon-based learning strategy and accept whatever the teacher explains without understanding the meaning.

PISA (Program for International Student Assessment), which focused on reading literacy, mathematics, and science, revealed that the quality of physics classes remains low. Indonesia ranks 71 out of 79 countries in science (Hopfenbeck et al., 2018), showing that the quality of science education is still low. Indonesian students' critical thinking skills are still very lacking (Saminan et al., 2016), according to the average pretest score of students less than 15%. Students in Bali still struggle with critical thinking. Riani et al. (2014) studied students' critical thinking skills in Bali. Their study shows that students lack critical thinking skills from a low average pretest score of 33.81 out of a scale of 100. It demonstrates that science education in Indonesia is still of poor quality. The fact that critical thinking skills are still lacking is another indicator of how well physics is being taught. Despite the need for training and development in learning, the students' critical thinking test results are still below average. It demonstrates how inadequate students' critical thinking skills are for learning physics.

Many factors affect students' low critical thinking skills and learning outcomes. One of the leading causes is that physics learning in schools still uses the lecture method. Students only receive information and questions in numbers and calculations (Sujanem et al., 2020). Physics problems are not designed with everyday phenomena. The initial study of critical thinking skills tests on physics material were carried out on high school students in Singaraja who had learned Uniform Linear Motion, Non-Uniform Linear Motion, Free Fall Motion, and Parabolic Motion. The average score of the eleventh science class students' critical thinking skills test ranges from 30.5 to 33.2 in the less category (Sujanem et al., 2020). The outcomes of the students' tests on critical thinking remain low, despite the necessity for training and development of critical thinking skills through education.

The low achievement of students' critical thinking skills occurs because, so far, education packaging is often not in line with the nature of learning and teaching physics.Teaching materials, for example, modules, are crucial to the learning process. Teaching materials convey teachers' learning messages to students to pique their curiosity and foster their thoughts, feelings, and interests. Physics learning would benefit from digital modules (Hold et al., 2017; Perdana et al., 2017). To enhance and empower our critical thinking skills, we can utilize modules as teaching materials (Rosnanda et al., 2017; Zekri et al., 2020).

The packaging of physics textbooks used as handbooks for students and teachers had not been packaged comprehensively, which contained presentations of real problems, essential concepts, and conceptual and contextual examples that integrated technology in a problem-based learning (PBL) environment. The world of education can benefit from this rapid technological development by making it simpler to obtain information in the form of text, images, videos, and animations (Sujanem, 2012). It is an effort to make electronic module technology more useful and efficient by adapting to its development. The importance of research related to the problem-based e-module is carried out considering that this e-module can be used to facilitate the acquisition of critical thinking skills, as stated by Sujanem (2017), Sujanem et al. (2018), and Sujanem et al. (2020). Other research results show that the importance and Efficacy of electronic modules are developed in physics studies to enhance the efficiency of students' independent work and competitiveness (Shurygin & Krasnova, 2016).

The existing physics teaching materials include textbooks, modules, and student activity sheets. High school physics teaching materials are still packaged linearly at this time: teaching materials consisting solely of concepts and principles, as well as practice questions, examples of questions and their responses. Students' critical thinking skills have not been developed through the packaging of physics teaching materials—modules and their implementation—through activities like problem formulation, inductive-deductive analysis, argumentation, and decision-making. Additionally, despite the development of ICT, the teaching materials that are currently available have not been packaged as electronic teaching materials, such as e-books or e-modules (Triyono, 2015; Dejene, 2020; Sujanem et al., 2020). E-modules are learning packages needed for particular subjects that allow students to learn independently and are equipped with videos, audio, simulations, quizzes, and interactive evaluations (Hill et al., 2015; Sujanem et al., 2018). Students' conceptual knowledge and representational fluency in physics might change due to using designed online resources as pre-teaching, and students become more conscious of their learning process (Rillero & Camposeco, 2018).

Based on the background, designing teaching materials as problem-based interactive physics or Probinphys e-modules is necessary. It allows students to achieve critical thinking skills. The e-modules are packaged in a Blended-PBL model. The blended PBL model blends face-to-face and online problem-based learning (Tan & Shen, 2017; Salari et al., 2018; Liu et al., 2020). This model presents problems as a stimulus for both face-to-face and online learning. The problems presented are very complex and unstructured and relate to the daily life of students (Yew & Goh, 2016; Tan & Shen, 2017). However, there are drawbacks to this PBL paradigm, which necessitates changes in students' attitudes and learning practices, as well as teacher's willingness to tolerate failure among students accustomed to traditional learning methods (Liu et al., 2020). Problem-based learning intends to help students recognize and resolve issues in the classroom and daily life while enhancing critical thinking skills (Savery, 2015; Nilson, 2016; Myers, 2017; Sulasih et al., 2018; Liu et al., 2020; Saputro et al., 2020). The presence of the PBL learning model is actually used to work on students' critical thinking skills, which, it just so happens, in settling physics concept requires the skills to analyze and assess to conclude (Masruro et al., 2021).

Probinphys e-modules are used to implement the Blended-PBL model. There are several theoretical foundations that support Probinphys e-modules. According to constructivism, learning means forming meaning (Pebriyanti et al., 2015; Rillero & Camposeco, 2018; Ismiyati et al., 2019). From what they see, hear, feel, and experience, students create meaning. The blended learning model can mean any form of instructional technology by training instructors to enhance learning transfer (Ng et al., 2020). A new revolution is brought about by incorporating ICT into education, particularly blended-based learning, and it offers opportunities to develop critical thinking skills and enhance learning outcomes (Sulaiman, 2013). Online PBL implementation enhances students' critical thinking skills in physics (Sulaiman, 2013; Sari et al., 2018; Hussin et al., 2018).

Critical thinking skills are higher after learning with the blended PBL model (Sulaiman, 2013). The website's problem-based learning (PBL) designs are jam-packed with data, illustrations, maps, and other resources (Sujanem et al., 2018; Sujanem et al., 2020). Students need assistance from teachers in using the internet efficiently. For PBL, the internet is a great resource (Sulaiman & Elnetthra, 2014). The Probinphys e-module developed is unique for its unstructured problems, physical phenomena, and important and strategic concepts. The concepts contain critical thinking skills, critical thinking skills examples, animations/simulations of physical phenomena, videos, and critical thinking skills exercises. It can be accessed online.

The primary objective of this study is to determine whether the Probinphys e-model efficient to enhance students' critical thinking abilities in physics learning at Singaraja High School. Problem formulation, argumentation, deduction and induction, and decision making are all indicators of critical thinking skills. The question at hand in this study is whether or not the Probinphys e-module in the Blended-PBL model efficient to enhance students' critical thinking skills while they are studying physics in high school.

METHODS

The research applied a one-group pretest and posttest design (O1 × O2) (Fraenkel & Wallen, 2012; Sugiyono, 2012). The symbols O1 and O2 represent the pretest and posttest. The symbol × represents the Probiphys e-module in the Blended-PBL model.

The learning steps are adopted from Arends (2007) in the five phases of the Blended-PBL model syntax based on the scenarios designed in the lesson plans. In phase 1, the orientation is on unstructured problems (ill-structure). Examples of problems are contained in the Probiphys e-module. In phase 2, the activities carried out: organizing students in face-to-face study groups, allowing students to access the Probiphys e-module. In phase 3, face-to-face investigation phase, inviting students to group themselves to understand and appreciate problems and carry out problem-solving through investigation experiment virtually, with the help of video labs. In phase 4, the teacher guides the group to do the analysis, helps students prepare investigation reports, facilitates students in question and answer discussions, conveys group discussion work in building CTS, and in phase 5: analysis and evaluation of activities facilitating the discussion process and evaluation of problem-solving, which is complex, solving CTS practice questions, evaluating reports of examples of everyday physics applications related to student subject matter sent via the internet, providing responses to student questions, and evaluating answers to student contextual practice questions sent via the Internet.

The efficacy of the Probiphys e-module in the Blended-PBL model is described based on data on enhancing student critical thinking skills (CTS) and student responses to the efficacy of the Probiphys e-module in the Blended-PBL model. The critical thinking skills test used is descriptive questions based on indicators from Ennis (2015): formulating problems, giving arguments, conducting deductive analysis, inductive analysis, making decisions, and conducting evaluations.

In learning using the Probiphys E-Module in the Blended-PBL Model, students were given a CTS test (pretest) in the beginning (O1) and the same test in the end (posttest) (O2). The Probiphys e-module in the Blended-PBL model, the subject of this research, was tested on groups A, B, and C of grade eleven high school students for the 2019-2020 academic year. Each group consisted of 29, 26, and 24 students, totaling 79 students. The selection of the group as the trial class was carried out randomly. The independent and dependent variables are this study's main variables. Problem-based interactive physics e-modules (Probiphys) are the independent variable, and students' CTS is the dependent variable. The test sheet comprises 15 items developed as a research instrument to measure students' CTS. The research instrument was validated and declared reliable by experts. Data on students' critical thinking skills were collected using a test instrument. Data were collected before (pretest) and after (posttest) students participated in the learning. The form of the test is an essay of problem narratives. Each test item refers to CTS indicators.

Research instrument validation is focused on content validity and construct validity. Experts carry out validation. Valid instruments are then tested on students learned about temperature and heat. There are 15 essay questions about the heating temperature that meet the criteria: Discrepancy Index (>0.20), Internal Consistency of Items (0.30-0.70), Item Difficulty Index (>0.30). The critical thinking skills test results were used to determine the efficacy of the Probinphys e-module in the blended-PBL model using the normalized gain, or N-gain, between the pretest and posttest. The efficacy of the e-module in enhancing critical thinking skills is if it meets the efficacy aspect. Aspects of efficacy were analyzed descriptively indicated by the students' critical thinking skills were classified as good. Using paired t-tests, the N-gain data were analyzed. N-gain criteria fall into the high category if g is less than 0,7, medium if g is less than 0,3, and low if g is greater than 0.

The significance of enhancing one's critical thinking skills was assessed using the paired t-test (Fraenkel & Wallen, 2012). Paired t-test was the method of data analysis, and SPSS version 25 was used. The requirements for using this data analysis technique must be met normality test or non-parametric analysis with Wilcoxon test analysis, and test the normality of the data using the Kolmogorov-Smirnov test. Next, an analysis of variance (ANOVA) will be carried out for consistency analysis (no difference) for the average enhancement in critical thinking skills using Probinphys e-modules in the blended-PBL model between groups A to C. The three homogeneous groups are met because the average N-gain for each of the three groups comes from a population with a normal distribution. Data on student responses to Probinphys e-modules in blended PBL were collected using a questionnaire. The components of students' responses are the novelty, their interest, their opinions, communication skills, and the novelty of communication skills in the use of Probinphys e-modules. The use of process skills and novelty of using process skills are also the component of students' responses. Analysis of students' response data used the Guttman scale. The percentage of students' response scores was used to determine the category of students' responses.

RESULTS AND DISCUSSION

The pretest and posttest score analysis for students' CTS indicator includes formulating problems, providing arguments, deductions, inductions, evaluations, decisions, and problem-solving. The analysis results of each student CTS indicator in groups A to C are presented in Table 1 to 3.

Table 1. Analysis of the Pretest and Posttest Score Results in Group A

No	Critical Thinking Skills Indicator	Pretest	Category	Posttest	Category
1	Giving arguments	7.6	Less	15.1	Very good
2	Formulating the problem	4.0	Very less	6.4	Enough
3	Performing induction analysis	4.9	Very less	11.8	Good
4	Analyzing deductively	5.6	Less	11.8	Good
5	Doing an evaluation	4.0	Very less	6.2	Enough
6	Making decisions and carrying out	5.6	Less	11.6	Good

Table 1 revealed that group A students' average score of critical thinking skills (CTS) indicators before they were taught with the Probinphys e-module was in the less and very less category. After students using the Probinphys e-module, the average student indicator was in a good category. The activities of formulating problems and conducting inductive analysis were rarely touched. After learning using the Probinphys e-module, which provides a process for obtaining CTS results with CTS indicators, the results for each CTS related to giving arguments were in the very good category. On the other hand, the acquisition of CTS indicators for conducting inductive analysis, conducting deductive analysis, and making decisions was in the good category. However, CTS indicators for formulating problems and evaluating are in enough categories.

Table 2. Analysis of the Pretest and Posttest Score Results in Group B

No	Critical Thinking Skills Indicator	Pretest	Category	Posttest	Category
1	Giving arguments	5.8	Less	15.1	Very good
2	Formulating the problem	4.0	Very less	7.1	Enough
3	Performing induction analysis	4.2	Very less	11.8	Good
4	Analyzing deductively	3.1	Very less	11.8	Good
5	Doing an evaluation	4.0	Very less	6.2	Enough
6	Making decisions and carrying out	6.0	Less	12.0	Good

Table 2 revealed that group B students' average score of critical thinking skills (CTS) indicators before they were taught with the Probinphys e-module was in the less and very less category. After using the Probinphys e-module, the average student indicator was in a good category. The activities of formulating problems and conducting inductive analysis were rarely touched. After learning using the Probinphys e-module, which provides a process for obtaining CTS results with CTS indicators, the results for each CTS related to giving arguments were in the very good category. On the other hand, the acquisition of CTS indicators for conducting inductive analysis, conducting deductive analysis, and making decisions was in the good category. However, the indicators of formulating problems and doing an evaluation are in enough category.

Table 3. Analysis of the Pretest and Posttest Score Results in Group C

No	Critical Thinking Skills Indicator	Pretest	Category	Posttest	Category
1	Giving arguments	5.8	Less	15.1	Very good
2	Formulating the problem	3.1	Very less	6.2	Enough
3	Performing induction analysis	4.2	Very less	11.8	Good
4	Analyzing deductively	3.3	Very less	11.8	Good
5	Doing an evaluation	4.0	Very less	6.2	Enough
6	Making decisions and carrying out	6.0	Less	11.8	Good

Table 3 revealed that group C students' average score of critical thinking skills (CTS) indicators before they were taught with the Probinphys e-module was in the less and very less category. After students were taught with the Probinphys e-module facility, the average student indicator was in a good category. The activities of formulating problems and conducting inductive analysis were rarely touched. After learning using the Probinphys e-module, which provides a process for obtaining CTS results with CTS indicators, the results for each CTS related to giving arguments were in the very good category. On the other hand, the acquisition of CTS indicators for conducting inductive analysis, conducting deductive analysis, and making decisions was in the good category. However, the acquisition of CTS indicators for formulating problems and doing an evaluating is in enough category.

The average pretest and posttest scores of groups A to C of eleventh-grade students of SMAN 2 Singaraja are displayed in Table 4.

Table 4. Pretest and Posttest Scores of Critical Thinking Skills

Description	Group A		Group B		Group C	
	Pretest	Post-test	Pretest	Post-test	Pretest	Post-test
The lowest score	7	47	9	51	9	44
The highest score	44	82	44	82	47	76
Mean	31.6	62.9	27.1	64.0	26.4	62.9
Ideal score	100	100	100	100	100	100
Number of students	29	29	26	26	24	24

In Table 4, the average score (mean) for the critical thinking skills before learning (pretest) for the three groups in a row is 31.6, 27.1, and 26.4 in the less category. After learning with Probinphys e-modules in the blended PBL, students' average score of critical thinking skills (posttest) for the three groups was 62.9, 64.0, and 62.9, in the good category.

The critical thinking skills average results of the three groups after using the Probiphys e-module were far from the CTS average scores before the students and the average scores of students who had received lessons on the same material. Table 1 shows the average pretest and posttest scores of groups A to C of eleventh-grade students are described in Table 1.

In addition, the enhanced critical thinking skills of three groups, in high category, are depicted in Figure 1.

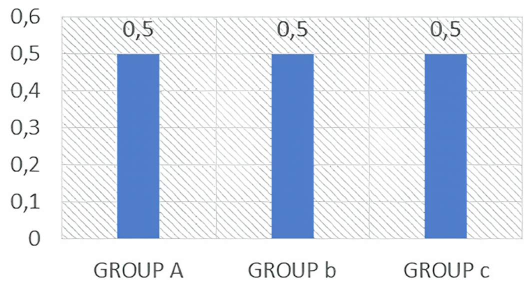

Figure 1. Average N-gain of Critical Thinking Skills

In Figure 1, students' critical thinking skills have enhanced on average by 0.5 points, which is categorized as moderate according to Hake (1999). Thus, problem-based physics e-module through blended learning is efficient in enhancing students' critical thinking skills.

Table 5 shows that the Paired t-test results between the pretest and posttest of the three groups' critical thinking skills met the normality and homogeneity criteria.

Table 5. Paired t-test Results between Pretest and Posttest scores

No	Data	Average test (t)	df	p (2-tailed)	Remark
1	Group A	-29,820	28	0.0000	Ho is rejected
2	Group B	-20,878	25	0.0000	Ho is rejected
3	Group C	-20.397	23	0.0000	Ho is rejected

In the three groups, the paired t-test results for the pretest and posttest critical thinking skills have a p-value less than 0.05 and a negative overall value, as shown in Table 5. Students' critical thinking skills were significantly different in statistics before and after using Probinphys e-modules. Students' critical thinking skills were higher after using Probinphys e-modules than before. The results of ANOVA on enhancing students' critical thinking skills also met the criteria for normality and homogeneity, as presented in Table 6.

Table 6. ANOVA Results on Enhancing Students' Critical Thinking Skills

No	Data	F	df	p	Remark
1	Average N-gain of the CTS of Groups A to C	1,761	76	0,179	Ho is accepted

*p < 0.05

The p-value for the ANOVA results for groups A to C is 0.179. It shows that the p-value is greater than 0.05 statistically, indicating no difference in the average enhancement in students' critical thinking skills. It is consistent at $\alpha = 5\%$ for all groups. Students' responses to the Probinphys e-module state that it is fun, engaging, motivating to learn, has an element of novelty, easy to learn for temperature and heat materials ranging from 80.0% to 100%, with an average of 92%.

Students' critical thinking skills fell into the low category on the pretest (Table 1). After employing Probinphys e-modules in a blended PBL, students' critical thinking skills moved into good category. According to the N-gain, students in the eleventh grade now have moderate critical thinking skills. There is also a significant enhancement on students' critical thinking skills. Therefore, the Probinphys e-module efficiently enhances students' critical thinking skills. It aligns with previous research findings, which state that blended learning enhances critical thinking skills (Rachman et al., 2019; Sujanem et al., 2020). Online learning enhances critical thinking skills (Sulaiman, 2013). Students' critical thinking skills also enhance after using problem-based hybrid learning (Pro-BHL) for physics (Sujanem et al., 2018). Physics learning with problem-based e-modules in blended PBL learning efficiently enhances students' critical thinking skills (Sujanem et al., 2020).

Because critical thinking skills have not been taught to students, their critical thinking scores were probably low before using the Probinphys e-module in the blended PBL and enhanced after using it. Figure 1 displays the 5% statistically significant enhancement in students' average critical thinking scores. Figure 1 displays the average N-gain value, which, by the criteria, is 0.5 for each group in the moderate category (Hake, 1999). This follows the findings of Iwung and Nugraha (2022). The achievement of critical thinking skills after learning is categorized as high.

The advantage of this physics e-module is the availability of links (hyperlinks) related to contextual learning with everyday problems or phenomena. The availability of material links to conceptual and essential problems provides opportunities for students to explore and make sense of physics concepts and deepen them.

In addition, another advantage of using the Probiphys e-module is that students are trained in achieving CTS indicators at each stage. The significant enhancement of critical thinking skills is because students are trained to achieve critical thinking skills indicators by using Probinphys e-modules at each stage. During problem orientation, students are trained to formulate problems. They look at the problem of temperature and heat daily, identify problems based on the theoretical basis, and perform deductive analysis. In organizing learning, students breakdown complex temperature and heat problems into basic ones. The investigation stage urges students to provide arguments, analyze inductively, give solutions or suggestions following the problem or theory (deciding), and conduct inductive analysis. When developing and presenting the work, students provide arguments, analyze deductively, evaluate, and make decisions. Students provide arguments, analyze inductively and deductively, make decisions, deliver application examples, and practice answers to critical thinking skills questions at the stage of analyzing and evaluating the solving process.

Critical thinking skills of students from all group enhance consistently, as displayed in Table 2. The N-gains in the three groups are not different from each other or consistent. Using Probinphys e-modules in the blended PBL can consistently enhance students' critical thinking skills. It aligns with schema theory; when reconstructing information, one adapts to his previous knowledge (Santrock, 2017). Furthermore, the study of the ICT integration model is the basis for the application of Probinphys e-modules in the blended PBL. This study gives access to higher critical thinking skills. Thus, by using Probinphys e-modules, critical thinking skills are higher after being given a blended PBL.

On the other hand, this finding is also strengthened by previous studies, which state that students' critical thinking skills enhance through implementing PBL online learning in physics (Eldy & Sulaiman, 2019; Rubini et al., 2019). E-module learning typically comes from a government-issued electronic bookkeeping center and is not interactive, solely allowing textbook-like reading (Sholeha et al., 2019). Due to students' easier access to learning materials from various sources and faster, more frequent access to learning materials, technology, and information substantially impact educational quality (Owen et al., 2017). Enhancement of critical thinking skills in learning through e-modules because in Probinphys e-modules in the blended-PBL concepts hyperlinks related to contextual learning with everyday problems or phenomena, the availability of conceptual and essential material links to problems to provide opportunities for students to explore and interpret physics concepts.

In learning with Probinphys e-modules, students can give meaning to learning, especially related to temperature and heat material. It is in accordance with schema theory, which expresses that when somebody remakes data, they adjust to their past knowledge (Santrock, 2017; Isna et al., 2017). It is likewise built up by learning theory which underlines the significance of meaningful learning prompting the constructivist theory. It expresses that students should find and change complex data assuming they believe the data should turn into their own. They can do it by weighing new data contrary to old rules and changing them when they are at this point not accommodating.

A rational theoretical foundation supports learning outcomes related to critical thinking skills. The pretest results show that students critical thinking abilities are lacking. This finding is consistent with initial study findings that public senior high school students in Singaraja had low critical thinking skills (Sujanem et al., 2020). The findings of students' critical thinking skills before learning using Probinphys e-modules in the blended PBL contradict the crucial benefits of critical thinking skills. Critical thinking is vital in education and is the primary goal of learning (Haghparast et al., 2014). Based on the data analysis results, students' critical thinking skills enhanced by 0.5. Generally, this enhancement is in the moderate category (Hake, 1999). Based on the average difference in test results between the pretest and posttest using paired t-tests, applying Probinphys e-modules can significantly enhance students' critical thinking skills at $\alpha = 0{,}05$. Thus, using Probinphys e-modules in blended PBL efficiently enhances critical thinking skills. This result aligns with previous research, which states that blended learning can enhance critical thinking skills (Rachman et al., 2019). Learning with problem-based modules can enhance critical thinking skills (Rubini et al., 2019). This is also in line with similar findings, which state that online enhances efficiently critical thinking skills (Sulaiman, 2013). Learning through Probinphys e-modules in the blended PBL can develop students' critical thinking skills. Essential skills like communication, cooperation, inquiry-based learning, peer learning, project management, collaborative and individual innovation, and creativity are efficiently produced by the PBL model (Lim et al., 2020). In addition, critical thinking skills include formulating problems, giving arguments, deduction, induction, deciding, and implementing (Ennis, 2015; Serevina et al., 2018). Integrating ICT in education, specially blended packaging brings a new revolution and provides opportunities for achieving critical thinking skills and higher learning outcomes.

The average students' response to the Probinphys e-module is in the very high category. Most students were happy, engaged, and motivated to learn. The e-module has an element of novelty and makes it easy to learn the temperature and heat material. The Probinphys e-module has novelty, the attractiveness of generating students' motivation and interest and gaining new communication skills using Probinphys e-modules.

CONCLUSION

Based on the results, several conclusions can be drawn. Using Probinphys e-modules in the blended PBL efficiently enhances students' critical thinking skills. Critical thinking skills enhance with an N-gain of 0.5, including the medium-level category. Students' critical thinking skills enhancement significantly with 0.05 after using Probinphys e-modules in blended PBL. Students' responses to Probinphys e-modules in the blended PBL are in the very high category.

REFERENCES

Arends, R. I. (2007). Learning to Teach, McGraw Hill Companies, Inc., 1221 Avenue of the Americas, New York, NY 10020.

Aufa, M. N., Rusmansyah, Hasbie, M., Jaidie, A., & Yunita, A. (2021). The Effect of Using e-module Model Problem Based Learning (PBL) Based on Wetland Environment on Critical Thinking Skills and Environmental Care Attitudes. *Journal of Research in Science Education*, *7*(3), 400-407

Brookfield, S. D. (2017). *Becoming a critically reflective teacher*. New York: John Wiley & Sons.

Dejene, W. (2020). Conceptions of teaching & learning and teaching approach preference: Their change through preservice teacher education program. *Cogent Education*, *7*(1).

Ennis, R. H. (2015). *The nature of critical thinking: outlines of critical thinking dispositions and abilities.*

Fraenkel, J. R., & Wallen, N. E. (2012). *How to design and evaluate research in education* (7th ed.). New York: McGraw-Hill.

Griffin, P. & Care, E. (2015). *Assesment and teaching of 21st century skills: Methods and approach*. New York: Springer

Hake, R. (1999). Analyzing Change/ Gain Score. Indiana: Indiana University.

Hill, M., Sharma, M. D., & Johnston, H. (2015). How Online Learning Modules can Improve The Representational Fluency and Conceptual Understanding of University Physics Students. *European Journal of Physics, 36*(045019), 1-20.

Hold, P., Erol, S., Reisinger, G., & Sihn, W. (2017). Planning and evaluation of digital assistance systems. *Procedia Manufacturing*, *9*, 143–150.

Hopfenbeck, T. N., Lenkeit, J., El Masri, Y., Cantrell, K., Ryan, J., & Baird, J. A. (2018). Lessons learned from PISA: A systematic review of peer-reviewed articles on the programme for international student assessment. *Scandinavian Journal of Educational Research*, *62*(3), 333–353. h

Hussin, W. N. T. W., Harun, J., & Shukor, N. A. (2018). Problem Based Learning to Enhance Students Critical Thinking Skill via Online Tools. *Asian Social Science*, *15*(1), 14-23.

Ismiyati, Festiyed, & Hamdi. (2019). Validity of physics learning module based on problem based learning to improve students metacognitive skills. *Journal of Physics: Conference Series*, *1185*(1).

Isna, R., Masykuri, M., & Sukarmin. (2017). Achievement of Learning Outcome After Implemented Physical Modules Based on Problem Based Learning. *Journal of Physics: Conference Series.*

Iwung, K., & Nugraha, A. R. (2022). Develop-ment of Webtoon-Based Physics E-Modules in Work and Energy Topics on Students' Critical Thinking Skills. *Journal of Teaching and Learning Physics, 7*(1), 63-71

Jatmiko, B., Prahani, B. K., Munasir, S., Wicaksono, I., Erlina, N., & Pandiangan, P. (2018). The comparison of OR-IPA teaching model and problem based learning model effectiveness to improve critical thinking skills of pre-service physics teachers. *Journal of Baltic Science Education*, *17*(2), 300.

Lim, B. C. Y., Liu, L. W. L., and Choo, C. H. (2020). "Investigating the effects of interactive e-book towards academic achievement". *Asian Journal of University Education*, *16*(3), 78-88.

Liu, C. X., Ouyang, W. W., Wang, X. W., Chen, D., & Jiang, Z. L. (2020). Comparing hybrid problem-based and lecture learning (PBL+ LBL) with LBL pedagogy on clinical curriculum learning for medical students in China: a meta-analysis of randomized controlled trials. *Medicine*, *99*(16).

Mason, J. (2017). *Qualitative researching*. London:Sage Publication.

Masruro, S., Sudibyo, E., Purnomo, T. (2021). Profile of Problem Based Learning to Improve Students' Critical Thinking Skills. *International Journal of Recent Educational Research, 2*(6), 682-699

Misbah, M., Mahtari, S., Wati, M., & Harto, M. (2018). Analysis of Students' Critical Thinking Skills in Dynamic Electrical Material. *Kasuari: Physics Education Journal (KPEJ)*, *1*(2), 103-110.

Mundilarto, M., & Ismoyo, H. (2017). Effect of problem-based learning on improvement physics achievement and critical thinking of senior high school student. *Journal of Baltic Science Education*, *16*(5), 761-780.

Myers, C. (2017). *Law professors' existential online lifeworlds: An hermeneutic phenomenological study.* Kansas State University.

Nilson, L. B. (2016). *Teaching at its best: A research-based resource for college instructors*. New York: John Wiley & Sons.

Ng, O. L., Ting, F., Lam, W. H., & Liu, M. (2020). Active learning in undergraduate mathematics tutorials via cooperative problem-based learning and peer assess-ment with interactive online whiteboards. *The Asia-Pacific Education Researcher*, *29*(3), 285–294.

Oliveras, B., Márquez, C., & Sanmartí, N. (2013). The use of newspaper articles as a tool to develop critical thinking in science classes. *International Journal of Science Education*, *35*(6),885–905.

Owen, S., Palekahelu, D., Sumakul, T., Sekiyono, E., & White, G. (2017). Systematic educational change and teacher skill-building in developed and developing countries: the importance of teacher peer learning groups. *Teacher Development*, 1–17.

Pebriyanti, D., Sahidu, H., & Sutrio, S. (2015). Efektifitas model pembelajaran perubahan konseptual untuk mengatasi miskonsepsi fisika pada siswa kelas X SMAN 1 Praya Barat tahun pelajaran 2012/2013. *Jurnal Pendidikan Fisika Dan Teknologi*, *1*(2), 92–96.

Pelawi, H. S., & Sinulingga, K. (2016). Pengaruh model PBLd an motivasi belajar terhadap hasil belajar peserta didik di kelas X SMA swasta sinar husni. *Jurnal Pendidikan Fisika, 5*(1), 32-37.

Perdana, F. A., Sarwanto, S., Sukarmin, S., & Sujadi, I. (2017). Development of e-module combining science process skills and dynamics motion material to increasing critical thinking skills and improve student learning motivation senior high school. *International Journal of Science and Applied Science: Conference Series*, 45–54.

Pursitasari, I. D., & Permanasari, A. (2013). Model Integrated Problem Solving Based Learning Pada Perkuliahan Dasar-Dasar Kimia Analitik. *Jurnal Ilmu Pendidikan*, *18*(2).

Puspitasari, D. (2019). Development of student worksheets based on problem based learning in static fluid. *Proceeding of the First International Graduate Conference (IGC)*, 379–385.

Rachman, A., Sukrawan, Y., & Rohendi, D. (2019). Penerapan model blended learning dalam peningkatan hasil belajar menggambar objek 2 dimensi. *Journal of Mechanical Engineering Education*, *6*(2), 145–152.

Riani, E. D., Sadia, I. W., & Swasta, I. B. J. (2014). Pengaruh Model Pembelajaran Sains Teknologi Masyarakat (Stm) Dalam Pembelajaran Biologi Bermuatan Karakter Terhadap Keterampilan Berpikir Kritis dan Kemampuan Pemecahan Masalah Siswa SMA. *Jurnal Pendidikan Dan Pembelajaran IPA Indonesia*, *4*(1).

Rillero, P., & Camposeco, L. (2018). The iterative development and use of an online problem-based learning module for preservice and inservice teachers. *Interdisciplinary Journal of Problem-Based Learning*, *12*(1), 14-23.

Rosnanda, D., Sarwanto, & Aminah, N. S. (2017). Pengembangan Modul Pembelajaran Berbasis Masalah Pada Materi Litosfer Untuk Meningkatkan Keterampilan Berpikir Kritis Siswa SMP. *Jurnal Inkuri*, *6*(3), 141–152.

Rubini, B., Septian, B., & Permana, I. (2019). Enhancing critical thinking through the science learning on using interactive problem based module. *Journal of Physics: Conference Series*, *1157*(2).

Salari, M., Roozbehi, A., Zarifi, A., & Tarmizi, R. A. (2018). Pure PBL, Hybrid PBL and Lecturing: which one is more effective in developing cognitive skills of undergraduate students in pediatric nursing course? *BMC Medical Education*, *18*(1),1–15.

Saminan, N. F., Gani, A., & Safitri, R. (2016). Peningkatan keterampilan berpikir kritis dan sikap ilmiah siswa dengan menggunakan model cooperative inquiry labs (CIL) pada materi suhu dan kalor. *Jurnal Pendidikan Sains Indonesia*, *4*(1).

Santrock, J. W. (2017). *Educational psychology*. McGraw-Hill Education.

Saputro, A. D., Atun, S., Wilujeng, I., Ariyanto, A., & Arifin, S. (2020). Enhancing Pre-Service Elementary Teachers' Self-Efficacy and Critical Thinking Using Problem-Based Learning. *European Journal of Educational Research*, *9*(2), 765–773.

Sari, W. P., Hidayat, A., & Kusairi, S. (2018). Keterampilan berpikir kreatif siswa sma dalam pembelajaran project based learning (pjbl) pada materi fluida statis. *Jurnal Pendidikan: Teori, Penelitian, Dan Pengembangan*, *3*(6), 751–757.

Savery, J. R. (2015). Overview of problem-based learning: Definitions and distinctions. In *Essential readings in problem-based learning: Exploring and extending the legacy of Howard S. Barrows*, *9*(2), 5–15.

Serevina, V., Astra, I., & Sari, I. J. (2018). Development of E-Module Based on Problem Based Learning (PBL) on Heat and Temperature to Improve Student's Science Process Skill. *Turkish Online Journal of Educational Technology-TOJET*, *17*(3), 26-36.

Shurygin, V. Y., & Krasnova, L. A. (2016). Electronic Learning Courses as a Means to Activate Students' Independent Work in Studying Physics. *International Journal of Environmental and Science Education*, *11*(8), 1743–1751.

Sholeha, J. J., Copriady, R., & Rasmiwetti. (2019). A The Development of E-Module Based on Problem Based Learning for the Main Topic of Electrolyte and Non-Solvent.*Applied* Electrolyte *Science and Technology*, *2*(2).

Siew, N. M., & Mapeala, R. (2016). The effects of problem-based learning with thinking maps on fifth graders' science critical thinking. *Journal of Baltic Science Education*, *15*(5), 602-616.

Sugiyono. (2012). *Metode penelitian pendidikan: pendekatan kuantitatif, kualitatif, dan R&D*. Bandung: Alfabeta.

Sujanem, R. (2012) Pengembangan Modul Fisika Kontekstual Interaktif Berbasis Web untuk Meningkatkan Pemahaman Konsep dan HasilBelajar Fisika Siswa SMA di Singaraja. *Jurnal Nasional Pendidikan Teknik Informatika (JANAPATI)*, *1*(2), 103-117

Sujanem, R. (2017). Pengaruh Model *Problem-Based Hybrid Learning* terhadap Keterampilan Berpikir Kritis Siswa SMAN 1 Singaraja. *Prosiding Seminar Nasional Pendidikan Sains PPs Unesa Tahun 2017*, E1135-E1142

Sujanem, R., Poedjiastuti, S., & Jatmiko, B. (2018). The Effectiveness of problem-based hybrid learning model in physics teaching to enhance critical thinking of the students of SMAN. *Journal of Physics: Conference Series*.

Sujanem, R., Suwindra, I. N. P., & Suswandi, I. (2020). The Effectiveness of problem-based interactive physics E-module on high school students' critical thinking. *Journal of Physics: Conference Series*.

Sulaiman, F., & Elnetthra, F. E. (2014). Integrated PBL approach: findings towards physics students' critical thinking. *International Journal for Innovation Education and Research*, *2*(2), 75-81.

Sulaiman, F. (2013). The Effectiveness of PBL online on physics students' creativity and critical thinking: a case study at Universiti Malaysia Sabah. *International Journal of Education and Research*, *1*(3), 1–18.

Sulasih, S., Sarwanto, S., & Suparmi, S. (2018). Physics learning with metacognitive approach through problem based learning (PBL) and reciprocal learning (RL) model viewed from students' critical thinking skill. *International Journal of Pedagogy and Teacher Education*, *2*, 9–77.

Tan, S., & Shen, Z. (2017). Hybrid problem-based learning in digital image processing: a case study. *IEEE Transactions on Education*, *61*(2), 127–135.

Triyono, M. B. (2015). The indicators of instructional design for e-learning in indonesian vocational high schools. *Procedia - Social and Behavioral Sciences, 204*, 54–61.

Vong, S. A., & Kaewurai, W. (2017). Instructional model development to enhance critical thinking and critical thinking teaching ability of trainee students at regional teaching training center in Takeo province, Cambodia. *Kasetsart Journal of Social Sciences*, *38*(1), 88–95.

Yew, E. H. J., & Goh, K. (2016). Problem-Based Learning: An Overview of its Process and Impact on Learning. *Health Professions Education*, *2*(2), 75–79.

Zekri, Z., Ganefri, G., & Anwar, M. (2020). Pengembangan Modul Pembelajaran Berbasis Proyek pada Mata Pelajaran Simulasi dan Komunikasi Digital SMK. *Pedagogi: Jurnal Ilmu Pendidikan*, *20*(1), 33–42.