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The Impact of Problem-Based Learning Electronics Module Integrated with STEM on Students' Critical Thinking Skills

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Abstract: One of the goals of learning physics is to help students develop their critical thinking skills. Preliminary studies conducted at SMAN 1 Pacitan show that the learning process is still teacher-centered with the lecture method and providing practice questions. Such a learning process causes the development of student's critical thinking skills to be less well-stimulated. Using e-modules in physics learning is expected to be a new solution to stimulate students' critical thinking skills. This research aims to determine the impact of Problem-Based learning physics electronic module integrated with STEM on students' critical thinking skills. The research method uses a quasi-experimental technique with a one-group pretest-posttest design. Data analysis used the N-gain test to determine the increase in students' critical thinking skills and the t-test to determine the effect of problem-based learning electronic module integrated with STEM on students' critical thinking skills. The sample was selected using a purposive sampling strategy. The samples involved were 34 students of class XI MIPA Senior High School Pacitan. The test was conducted to collect data on students' critical thinking skills. Research data was collected using an essay test of critical thinking skills totaling twelve valid questions with a reliability coefficient 0.70. Before the N-gain test was carried out, the normality, homogeneity, and t-test were first carried out. In the normality test, the data is normally distributed. In the homogeneity test, the data is homogeneous. Based on the paired sample t-test, it shows that there is a significant difference between pretest and posttest critical thinking skills with a sig. (2-tailed) <0.05, which indicates that the problem-based learning electronic module integrated with STEM has a positive effect on students' critical thinking skills. By acquiring an N-Gain score of 0.76 in the high category, the PBL physics electronic module integrated with STEM on mechanical wave characteristics material can improve students' critical thinking skills.

Keywords: Critical thinking skills; Electronics module; PBL; STEM.

Introduction

Physics lessons are often felt challenging to learn and often make students complain. This resulted in students needing more motivation to learn physics. Physics learning is still teacher-centered, rote, and unrelated to real-life and technological developments. Learning is a direct or indirect interaction that occurs between teachers and students. In learning physics, it does not only contain several theories or formulas but understanding the various concepts. Physics learning facilitates students to develop 4C, namely critical, creative, collaboration, and communication skills. One of the essential competencies to be developed in the 21st century is critical thinking skills. Therefore, the learning process is expected to train students to think critically. Students hone their critical thinking skills when faced with everyday problems. The learning process that hones essential thinking skills is inseparable from the teacher's role as a facilitator. Teachers still dominate learning (teacher-centered) and need to develop critical thinking skills. This is in line with the opinion of Hairida (2016) who states that a teacher-centered learning process cannot improve students' critical thinking skills.

Based on observations made, especially in physics learning at SMA N 1 Pacitan, the school applies the 2013 Curriculum for class XI, but learning activities are still centered on the teacher. Implementation of education

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still uses the lecture method, so the teacher explains the material as a whole first and then directs students to work on the questions in the book. Students tend to be passive, and the role of students in learning activities is relatively low, so the learning process is still centred on the teacher. In this regard, Abidin, (2016) suggests that teachers should be able to find tactics so that they can support and develop students' needs based on the potential that students already have.

Similarly, one of the goals of learning physics is to help students develop their critical thinking skills. Critical thinking skills are not only necessary for success in education, especially learning, but are also beneficial for students. Students who can think critically can navigate globalization and increasingly fierce competition (Gelora et al., 2022). The development of these critical thinking skills can occur because learning physics includes complex problems that can challenge students in applying the ability to analyze and present arguments, provide clarification of opinions, and generalize conclusions based on data. Critical thinking includes applying, analyzing, synthesizing, evaluating the information obtained and generalizing the results obtained from observation, experience, reflection, reasoning or communication. Critical thinking is not necessarily attached to someone from birth. However, critical thinking skills can be developed through students' direct experience in dealing with problems. If students are accustomed to using the abilities above, critical thinking skills will be able to develop.

Several factors affect students' low critical thinking skills, namely, the teacher still uses a monotonous learning model, meaning that students only take notes and listen to the teacher's explanation. Teachers need to use attractive learning models, making students more energized quickly. In this case, subject teachers especially need to find and apply an attractive learning model to help students understand and be able to change students' critical thinking skills to be higher. The teacher's task to improve students' critical thinking skills is to provide a learning environment that can encourage students to use their critical thinking skills. The Problem Based learning model is one of the learning models that can provide a learning environment that supports critical thinking skills. PBL is based on a problem to arouse students' curiosity to investigate the problem. When students carry out investigations, students use the stages of critical thinking skills such as analyzing evidence and making decisions based on the investigation results. Research that has been done previously using the Problem-Based Learning model, namely Permata et al. (2022) suggests that the Problem-Based Learning model is a learning model that focuses on a problem so that it can be a challenge for students to solve the problems presented by the teacher. The PBL model affects learning outcomes, scientific process abilities, and students' critical thinking skills. The PBL model could improve students' critical thinking skills and increase student activity and learning outcomes (Yulia & Salirawati, 2023).

Learning science, especially physics, is closely related to technology. Technology can help and support the student learning process. These conditions allow integration in physics-oriented learning with Science, Technology, Engineering, and Mathematics (STEM). Through STEM learning, students are trained to carry out scientific processes, think at a higher level, and are familiar with the technology so that they can be used as provisions for living in society and solving problems faced in everyday life related to the STEM field of science Rasmi et al. (2023). The STEM approach to learning physics is expected to present meaningful learning innovations for students through systematically integrating knowledge, concepts, and abilities (Ariyatun & Octavianelis, 2020).

The STEM approach can develop students' abilities in the changing everyday lives of the 21st century. STEM can also make learning more relevant and meaningful for students so that students' attitudes and thinking skills can improve (Stohlmann, 2014). The four aspects of the STEM (Science, Technology, Engineering, and Mathematics) approach are a harmonious unity between problems that occur in the real world and Problem-Based Learning (PBL), so these two things can collaborate to improve students' critical thinking skills (Selisne et al., 2019). The PBL model and the STEM approach can be integrated into the learning process because these two models and approaches are initiated by a problem (Syukri et al., 2018).

Research on the application of STEM-based PBL models is still rare. Based on research conducted by Cahyaningsih & Roektiningroem (2018), STEM integrated Problem-Based Learning-based science learning significantly influences critical thinking skills and cognitive learning outcomes in the moderate category. In addition, research by (Laforce et al., 2017) shows that Problem-Based Learning may be a strategy to increase student interest in the STEM field. Secondary schools implementing STEM tend to have intrinsic motivation and higher abilities in science or other STEM subjects than non-STEM schools. They found that students' perceptions of their PBL experiences were related to scientific attitudes.

PBL is a learning model that presents contextual problems that trigger students to learn. The PBL model with the STEM approach is learning integrated with science, technology, engineering, and mathematics to foster students' creativity by solving everyday problems (Nurhasnah et al., 2022). STEM integration in problem-based learning can guide students to solve problems given in groups, thus encouraging students to work together who are responsible for their work independently and can manage discussion patterns that match the circumstances of their respective groups (Arisa & Suryani, 2022).

Along with the development of technology, where the use of electronics influences the needs in life. The education sector is also not spared from its influence by using of technology and teaching aids in schools and other educational institutions (K. A. Lawless., 2007). One of them is the electronics module, a digital module. The required electronics module is an interactive electronics module that contains images, variations of writing, sound, animation and even video to help improve critical thinking skills. As part of electronic-based education, e-modules enable students to learn to use electronic devices to communicate and convey information. Electronic modules are interactive, and their usability is considered an essential factor in their design. Additionally, it includes audio, video, and animation elements, as well as tests and quizzes for students to take and receive feedback (Noer, 2020).

The electronic module developed by the researcher utilizes with WIX.com website. WIX is a web design developer platform without the need to use coding. WIX is considered friendly for beginners because it carries drag-and-drop features and various ease of operation. Through the convenience of the features offered, the WIX website can be used as a learning medium by considering the characteristics of the material and the needs of students (Sekarningsih et al., 2021). The use of WIX to do electronic modules is expected to attract student attention and make students active in online learning so that they can achieve learning goals, one of which is critical thinking skills.

Some previous research on the use of Problem-based learning electronic modules integrated with STEM was conducted by Serevina & Sari (2018), which explained that applying PBL-based electronic modules can improve science process skills. Using PBL-based E-modules provides an in-depth conceptual understanding of the cognitive, affective, and psychomotor domains that support learning motivation and problem-solving abilities that enhance learning outcomes. The PBL-based module directs students to find concepts independently and develop critical thinking skills. Research by Solihudin et al., (2018) regarding the development of electronic modules shows that electronic modules can improve the achievement of high school physics knowledge competencies and critical thinking skills. Research conducted by Pane et al., (2021) entitled Development of STEM-integrated Problem-Based Learning-based electronic physics modules to Improve high-level thinking skills in Static Fluid Materials shows results of teaching materials developed based on electronic modules is necessary to have teaching materials in the form of electronic modules that refer to 21st-century skills in the form of high-level thinking skills. From the description above, this research aims to see how the Problem-based learning electronic module integrated with STEM can improve students' critical thinking skills on the material characteristics of mechanical waves for class XI SMA.

Method

The type of research used in this study is experimental. According to (Sugiyono, 2010), experimental research methods can be interpreted as research methods used to look for the effect of specific treatments on others in controlled conditions. Based on this opinion, it can be understood that experimental research is always carried out by giving treatment to research subjects and then seeing the effect of the treatment.

The quasi-experimental method was applied using a one-group pretest-posttest design. Quasi-experimental is a study conducted in only one group. No control group was involved in this study. This design is used because there is a pretest before being given treatment. The treatment results can be known more accurately because they can be compared with the conditions before treatment. The following is an overview of the test design using the one-group pretest-posttest design (Sugiyono, 2010), as Equation 1.

$$O_1 \; X \; O_2. \quad (1)$$

Information:

O_1: Pretest

X Giving treatment (learning with PBL e-modules integrated with STEM)

O_2: Postest

The steps of the method in this study are as follows:

1. Develop a test instrument for students critical thinking skills.
2. Test the test instrument before it is used for data collection (validation & reliability).
3. Students are given a pretest by giving a test of critical thinking skills.
4. We are giving treatment to students in the form of implementing STEM-integrated PBL-based electronic modules developed using a website.
5. Students are given a final test (posttest) by giving a critical thinking ability test.
6. Data analysis includes a prerequisite test (test for normality, homogeneity, and paired sample t-test).

7. Perform the N-Gain test to measure electronic modules' efficacy in increasing students' critical thinking abilities.

This study's sample consisted of 34 of class XI SMA N 1 Pacitan students. The sample was selected using a purposive sampling strategy, provided that class XI MIPA students had been taught the basics of waves. Physics learning uses a Problem-based learning electronic module integrated with STEM on the material of mechanical wave characteristics. Electronic modules are arranged on a website so students can access them using laptops or smartphones. According to Ennis, critical thinking skills are a research parameter that consists of five aspects: basic clarification, the bases for a decision, inference, advanced clarification, supposition and integration (Ennis, 1995).

Tests are given to collect data on students' critical thinking skills. The test instrument contains descriptions of twelve valid items, consisting of aspects providing essential explanations for two items, aspects providing a basis for a decision for two items, aspects concluding three items, making further explanations for three items, and providing responses and integration/tactics for two items. The instrument test used has previously been tested on children and is known to have a reliability value of 0.70. Students are given an initial test (pretest) by distributing critical thinking skills test instruments to groups of students, followed by treatment and a final test (posttest) by distributing critical thinking skills test instruments once again. The initial test was carried out before leaving the treatment by implementing a PBL electronic module developed using a website integrated with STEM, then continued with the final test.

The normalized N-Gain test was used to measure electronic modules' efficacy in improving students' critical thinking skills. Prerequisite tests, such as normality, homogeneity, and the Paired Sample T-Test, are performed before the normalized N-Gain test. Paired sample t-test to determine the effect of critical thinking skills on students. The research hypothesis is as follows:

H_0: The difference in pretest and posttest scores is significant.

H_1: There was no significant difference in scores between the pretest and posttest.

Criterion H_0 is accepted if only the significance value (p) is below 0.05 ($p < 0.05$), and H_0 is rejected when the significance value (p) is above 0.05 ($p > 0.05$).

The magnitude of the increase in students' critical thinking skills is calculated using the N-gain score with the formula in Equation 2:

$$N - Gain\ (g) = \frac{\bar{x}posttest - \bar{x}pretest}{\bar{x}max - \bar{x}pretest} \quad (2)$$

Then the n-gain calculation results are presented using the following criteria as Table 1,

Table 1. N-Gain calculation results

Value	Criteria
< 0.7	High
0.7-0.3	Medium
>0.3	Low

(Hake, 1998).

Result and Discussion

To collect data, pretest and posttest on students' critical thinking skills were used. Covers five areas: basic clarification, the bases for a decision, inference, advanced clarification, supposition and integration. Figure 1 presents the results of tests of students' critical thinking skills, including the minimum average and maximum values.

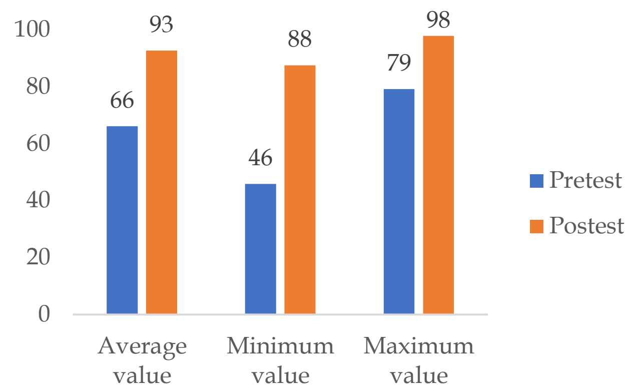

Figure 1. Data on Students' Critical Thinking Skills Test Results

Figure 1 depicts students' critical thinking skills test results before and after receiving the electronic module using the STEM-integrated PBL Web-based. Before being given the electronic module, students obtained pretest results with an average score of 66. The lowest score in the pretest was 46, and the highest score during the pretest was 79. Students obtained an average score of 93 after treatment in learning using Problem-based learning electronic modules integrated with STEM, with the lowest score of 76 and the highest score of 98. From the critical thinking skills test results, students' abilities increased after using Problem-based learning electronic modules integrated with STEM. The pretest average was 66 and the posttest average was 93 (posttest score > pretest score). This shows that students have increased critical thinking skills.

Students' critical thinking skills have increased after learning using Problem-based learning electronic modules integrated with STEM, as shown in Figure 1. The successful use of electronic modules designed by researchers is determined by increasing students' critical thinking skills. A normalized N-Gain Test is performed to determine the electronic module's effectiveness. Prerequisite tests include normality tests, homogeneity tests, and sample T-tests before carrying out the normalized N-Gain test. The significance value obtained from the normality test is managed to interpret the results.

The data is normally distributed after the significance value (p) exceeds 0.05. The homogeneity test is designed to determine the data in the critical thinking skills of a homogeneous variable or vice versa. In the homogeneity test, if the significance value (p) is below 0.05, then the data variant is considered heterogeneous; After the significance value (p) is above 0.05 ($p > 0.05$), the data variance is declared homogeneous (Setyawan, 2020). Table 2 summarizes the test scores of students' critical thinking skills at the pretest and posttest.

Table 2. Pretest-Posttest Prerequisite Test Values

Conducted test	Significance	Conclusion
Normality (Shapiro-Wilk)	Pre-test = 0.152 Post-test = 0.070	Data normally distributed
Homogeneity (Levene's Test)	0.166	Data is homogeneous
Differences of Pretest and Posttest result (Paired sample t test)	0.000	There is difference between pretest and posttest scores

Prerequisite tests in normality, homogeneity and Paired Sample T-Test were conducted using SPSS 22 software. The normality test was carried out with the Shapiro-Wilk test. This is due to the number of samples of less than 50 participants. Based on the results of the normality test, the pretest had a significance value (p) of 0.152, and the posttest obtained a value (p) of 0.070 ($p > 0.05$). Because the significance value (p) for both the pretest and posttest are above 0.05, the data on students' critical thinking skills can be assumed to be normally distributed. Furthermore, this type of Levene test is used to test homogeneity. Based on the results of the homogeneity test, a significance value (p) of 0.116 ($p > 0.05$) was obtained, indicating homogeneous data. Then a Paired Sample T-Test was carried out to look for significant indications of differences in students' critical thinking skills before and after treatment using Problem-based learning electronic modules integrated with STEM. On the results of the Paired Sample T-Test, a significance value (p) of 0.000 ($p < 0.05$) indicates a significant difference in students' critical power. Following the prerequisite test, the normalized N-Gain test is used to assess students' learning motivation increasing. The N-Gain score of students' critical thinking skills shows 0.76 according to calculated data, which is included in the high level (Hake, 1998).

In the STEM approach to the PBL learning process, students are directed to open the e-module and follow the available paths by observing, asking, trying, associating, and communicating a natural phenomenon commonly experienced in everyday life. The next step is for students to formulate problems provided in the e-module. Students can develop critical thinking by identifying possible alternative answers found. In the next stage, students find a solution to a problem and will take steps to solve a problem. The project will hone students' critical thinking in the design stage. At the end of the student stage, the teacher guides students so they can model their mathematical equations in the material being studied. At this stage, students gain new knowledge by using previously acquired knowledge so that in the learning process, students can solve problems (Budiyono et al., 2020).

In this study, learning was carried out in the classroom by opening an e-module for discussion, while experimental or experimental activities were carried out virtually using the Phet Simulation virtual laboratory application. The following is an overview of learning activities and practicum in research.

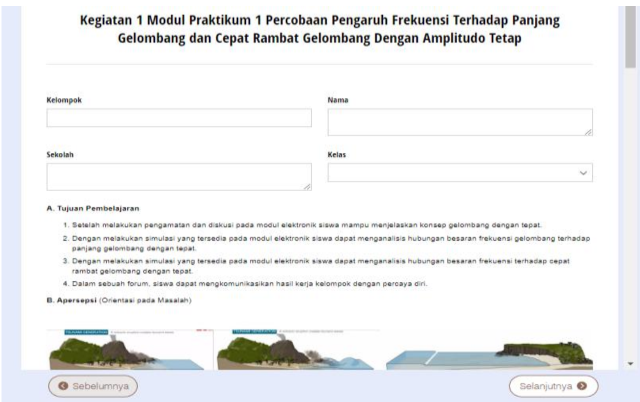

Figure 2. Learning activities in e-modules with Problem Based Learning integrated STEM

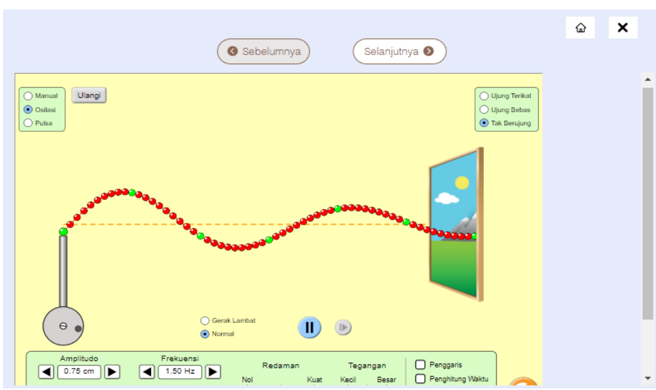

Figure 3. Mechanical wave characteristics material experiments using a Phet Simulation

The researcher's electronic module contains sample questions in each sub-material and an evaluation at the end of the lesson (assessment at the end of the lesson). The evaluation has two sub-evaluations: cognitive evaluation and evaluation of critical thinking skills. The presentation of practice questions is intended so that students can measure their abilities during the learning process so that students can evaluate their strengths and weaknesses in studying the sub-matter. Evaluations carried out by students on themselves can help students develop themselves to be better at learning and foster student initiative to try better in every lesson. The presentation of evaluation questions is intended so that students can measure their abilities after receiving lessons from the teacher so that students can self-evaluate after finishing studying a material or chapter. The following is a display of the e-module regarding the sub-evaluation.

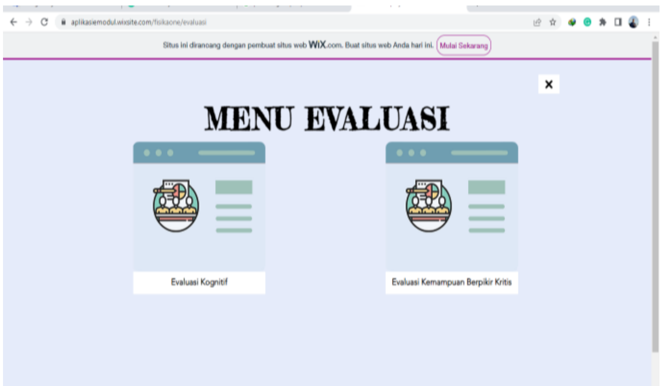

Figure 4. The evaluation has two sub-evaluations: cognitive evaluation and evaluation of critical thinking skills.

The Problem-based learning electronic modules integrated with STEM also contains problems in life according to the material on the characteristics of mechanical waves. The Problem-based learning electronic modules integrated with STEM invites students to participate in various problem-solving activities, such as learning videos, simple practicums, or simulation-based practicums, followed by discussions. This stage can awaken the students' minds to be more active. Students are encouraged to seek information with their thoughts through simple practicums or practicums using simulations rather than being given information directly by the teacher. The learning process continues with the assessment stage, where students are given various questions to answer. This stage encourages students to think critically to solve and respond to the problem. In addition, problem-solving steps are guided by the STEM-integrated Problem-Based Learning syntax. PBL is the whole of learning to bring up problem-solving thoughts, starting from the beginning of learning synthesized and organized into a problem so that it can familiarize students with understanding concepts by constructing their knowledge (Kurniati et al., 2021).

Learning with the STEM integrated Problem-Based Learning model makes students more active because learning comes from real-life problems, so learning is not abstract and more relevant to students' lives. In addition, the Stem Integrated Problem Based Learning model is a learning model that can help students in conceptual maturation because students are asked to find solutions by using thinking skills and gathering information through discussions and practicum activities (Jolly & Jacob, 2012). In the STEM integrated Problem-Based Learning process, students must produce work in every learning cycle. The work is an implementation of the engineering aspect; in the engineering aspect, students are asked to apply the knowledge they have acquired to a design or work.

Based on the pretest and posttest analysis results, an increase in all aspects of students' critical thinking skills was observed. Figure 2 illustrates the average increase in the N-Gain score for each aspect of students' critical thinking skills.

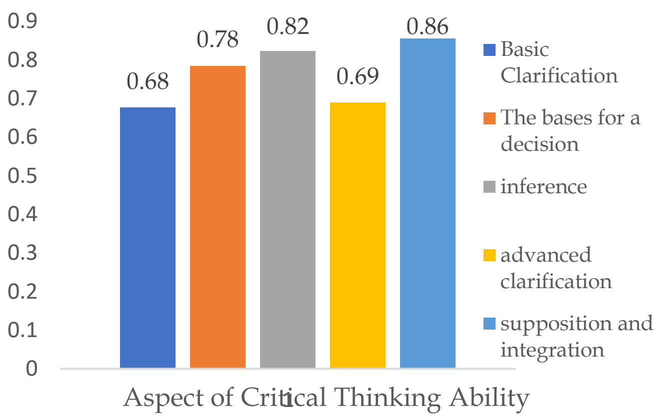

Figure 5. Average N-Gain for each aspect of critical thinking skills

Based on the table above, each aspect's gain score for critical thinking skills has a score. Regarding essential explanations, the average pretest score was 53.3, the posttest was 84.9, and N Gain was 0.676 in the moderate category. The aspect of providing a basis for a decision obtained an average pretest score of 70.95, a posttest of 93.75 and an N Gain of 0.78 in the high category. The concluding aspect obtained an average pretest score of 73.7, a posttest of 95.3 and an N Gain of 0.82 in the high category. Making further explanations obtained an average pretest score of 67.6, a posttest of 89.9 and an N Gain of 0.69 in the moderate category. Aspects of providing feedback and integration/strategy and tactics obtained an average pretest score of 60.2, posttest of 94.1 and N Gain of 0.86 in the high category.

According to Hake 1998, Gain is more than or equal to 0.3, and less than 0.7 is a moderate criterion. A gain of more than or equal to 0.7 and less than 1.0 is a high criterion. Electronic modules developed to stimulate students' critical thinking skills through learning the STEM-integrated PBL model stages related to aspects of critical thinking skills such as elementary clarification, inference, fundamental support, strategy and tactics, and advanced clarification improves their ability in terms of critical thinking.

Based on the pretest and posttest assessment results, the student's critical thinking skills scores increased in the high gain N category of 0.76. Research by (Cahyaningsih & Roektiningroem, 2018) states that the STEM integrated Problem-Based Learning model can improve critical thinking skills and cognitive learning outcomes. The STEM-integrated problem-based learning model can improve students' critical thinking skills, as indicated by the results of the N-gain and t-test. The independent sample t-test showed a significant difference between the critical thinking skills of the control group and the experimental group, while based on the paired sample t-test, the sig value. (2-tailed) < 0.05, which indicates that the STEM-integrated problem-based learning model has a positive effect on students' critical thinking skills (Ariyatun & Octavianelis, 2020).

The PBL learning model combined with STEM can increase the average student's critical thinking skills. Integrating STEM into the learning model will make learning more meaningful, especially related to students' daily problems. Through STEM-integrated PBL learning, students are challenged to think critically and creatively and innovate to solve existing problems through teamwork. Research conducted by Putri et al. (2020) to measure the improvement of students' critical thinking skills with the results of the STEM-integrated PBL model can improve high school students critical thinking skills. This assessment stage is associated with the evaluation of learning. At this point, both during the learning process and at the end of learning, learning evaluation must be carried out.

STEM-integrated problem-based learning is carried out by presenting problems and questions, facilitating investigations, opening dialogues with students and actualizing environmental literacy and student creativity (Rosidin et al., 2018). In the learning phase, STEM-integrated problem-based learning allows elaboration, collaboration and collaborative interaction of students in analyzing problems and the reporting process. Through STEM-integrated problem-based learning, students show a positive attitude, achieve integrated conceptual and procedural knowledge, and demonstrate active behavioural intentions (Lou et al., 2011). Applying STEM-based learning requires changing the learning model from teacher-centred to student-centred learning and individual learning to collaborative learning, emphasizing creativity and problem-solving in applying scientific knowledge (Doyan et al., 2023).

Figure 6. Students’ activities to apply e-modules

Problem-based learning electronic modules integrated with STEM can attract students' attention and make them more active during learning. Students' willingness to solve the difficulties and problems presented can positively impact their critical thinking skills (Kusuma & Hamidah, 2019). Details of each aspect of students' critical thinking skills are explained below:

Basic Clarification

The ability of students to answer questions and provide simple explanations for the problems given shows that there is an aspect of essential clarification. This is evidenced by the ability of students to make hypotheses about the effect of frequency on wavelength and the velocity of wave propagation with a fixed amplitude. Answering this hypothesis allows students to express their opinions or ideas after seeing phenomena and formulating problems. Furthermore, this Problem-based learning electronic module integrated with STEM is designed to involve students in learning. Both are active in action and action in problem-solving, and decision-making. Based on the pretest and posttest score analysis, the aspect of providing a basic explanation has increased with an N-Gain value of 0.676, which is moderate, according to Hake (1998). This is because in the learning process using STEM-integrated PBL-based electronic modules, students are used to being given problems that make them trained to answer questions with various ideas. In addition, students also carry out practical activities using simulations. As a result, besides thinking, students will be involved in action, which will improve their critical thinking skills. Student participation in learning will strengthen their critical thinking skills (Fadilla et al., 2021).

The Bases for a Decision

The aspect of providing a basis for a decision can be seen in the ability of students to develop basic skills in making observations. Students are asked to prove a case or problem and then apply their findings to other problems. Providing a basis for a decision has increased with an N-Gain score of 0.78, categorized as high based on the analysis of pretest and posttest scores. This happens because students are used to making observations and considering the results of their observations or those of their friends during discussions on STEM-integrated PBL-based electronic modules. Students can determine whether an observation result can be trusted by considering the results of their observations or those of their friends. Making observations and considering the results of observations also trains students to think critically because students in groups must convey ideas to find solutions to existing problems and then produce works. This makes children work hard at thinking, directly improving students' higher-order thinking skills (Haryadi et al., 2021).

Inference

The inference aspect can be seen from the students' ability to conclude according to the results and analysis they obtained. These events can be observed based on the ability of students to report the results of current measurements and determine the uncertainty value. Following the pretest and posttest scores analysis, the inference aspect is improved with an N-Gain value of 0.82, categorized as high. This is because, during the learning process using STEM-integrated PBL-based electronic modules, students are accustomed to processing data and drawing conclusions from the results of the practicum they are doing. The inference aspect emphasizes that students can think critically in making conclusions from the data they obtain (Pritananda et al., 2017). Therefore, familiarizing students with data processing and drawing conclusions can improve critical thinking skills in concluding aspects.

Advanced Clarification

The aspect of making further explanations refers to the ability of students to provide additional explanations, which are related to the activities of making and considering definitions and assumptions. This is shown by the student's ability to analyze each question provided in the worksheets from each experiment/simulation. Students are also directed to be able to explain the results of experiments by doing group presentations. Based on the analysis of the pretest and posttest scores results, the inference component has increased with an N-Gain score of 0.69, categorized as moderate (Hake, 1998). This is because when the Problem-based learning electronic modules integrated with STEM are used in the learning process, students are accustomed to making definitions based on their thoughts and self-explanations based on the results they get when presenting at the discussion stage. Students are taught how to develop ideas and explain them during presentations. Students are trained to develop and deepen ideas when giving group presentations in their unique way (Yustina et al., 2022).

Supposition and integration

Providing responses and strategies/tactics is related to students' abilities in developing strategies and tactics, which include activities to determine an action. This can be seen in the ability of students to develop strategies or tactics to determine the practical steps. The strategy and tactic aspects improved with an N-Gain score of 0.86, placing them in a high category, per the pretest and posttest scores analysis. This is because students are used to using Problem-based learning electronic modules integrated with STEM to build answers to the difficulties presented by the teacher and choose what steps to take to overcome these problems during the learning process. Someone will go through a rational process before deciding whether to do or believe something (Siahaan & Meilani, 2019).

Conclusion

Based on the study's results, the STEM-integrated problem-based learning model can improve students' critical thinking skills, as indicated by the N-gain results. Before the N-gain test, the normality, homogeneity and t-test were first carried out. In the normality test, the data is normally distributed. In the homogeneity test, the data is homogeneous. Based on the paired sample t-test, it shows that there is a significant difference between pretest and posttest critical thinking skills with a sig. (2-tailed) <0.05, which indicates that the STEM-integrated problem-based learning model has a positive effect on students' critical thinking skills. By acquiring an N-Gain score of 0.76 in the high category, the Problem-based learning electronic modules integrated with STEM on mechanical wave characteristics material is helps strengthen students' critical thinking skills.

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Author Contributions

Kevin Adhelacahya: writing-original draft preparation, result, discussion, methodology, conclusion; Sukarmin and Sarwanto analysis, proofreading, review, and editing.

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Conflicts of Interest
The authors declare that there is no conflict of interest regarding the publication of this paper.

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