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The Effectiveness of Problem-Based Learning with Integrated STEM Approach in Improving the Critical Thinking Skills

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Abstract

The research aimed to know the effectiveness of problem-based learning with STEM approach to improving the X MIPA students' critical thinking skills. The research was done in SMA 1 Purwantoro. Employing one group pretest-posttest design, this simple action research involved sampling of 35 students of X MIPA class in the 2020/2021 cohort. The technique of taking the sample was simple random sampling. The instruments were the test, the self-efficacy questionnaire, and the learning response questionnaire. The result of the research showed that the problem-based learning with STEM approach was effective in improving the X MIPA students' critical thinking skills, as shown from the result of Wilcoxon rank signed test hypothesis testing. The impact of the research could develop the students' critical thinking skills in order to grow a problem-solver character.

Keywords: *critical-thinking skills; effectivity; PBL; STEM*

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INTRODUCTION

Humans live in the 21st century with various developments on knowledge, technology, and machines, such as car. The increase of the number of cars becomes the supply of accident rates with fluctuating increases [1,2], causing negative impacts caused by vehicles, humans, and physical environment [3], so preventive efforts are needed, such as safety riding counseling [4], and more curative efforts are needed.

Overcoming the problem of accidents requires human resources. Metamorphosed education transforms students into a generation who is ready to contribute to the 21st century. The purpose of education in article 3 is a benchmark for the success of education [5]. The provision of problem-solving skills with critical thinking as the main skills through problem-based learning models with STEM needs to be provided.

Problem-based learning (PBL) model refers to learning activities to solve problems with intelligence [6]. PBL is the ideal choice based on evidence to fill the critical thinking gaps and highlight the strengths of generations [7]. There is an increase in critical thinking skills with the PBL-SET learning model [8]. It confirms that PBL is suitable for critical thinking enhancement. PBL needs to be integrated with the STEM approach in order to optimize the ability of students in terms of science, mathematics, technology, and machines to create students who think critically and have a problem solver spirit. Using the STEM approach provides an increase in critical thinking with a significance of 0.01 [9]. Thus, strengthening STEM is suitable for critical thinking improvement research.

Critical thinking needs to be developed. Previous studies have shown that low critical thinking is caused by various factors. In observations of several high schools in Tanjungpinang city, little research related to critical thinking profiles is found so educators did not know critical thinking skills [10]. The results of observations in SMAN 1 Sindang Indramayu showed that students' critical thinking level is low, using only the method of demonstration, lecture, and discussion [11]. In preliminary studies in senior high school in Sako sub-district and senior high school Alang-Alang Lebar, critical thinking tests did not match the indicators, mostly categories C1-C3 [12].

According to a quick observation in the class from another study, it was found that the learning did not relate to direct problems, especially accidents. The STEM approach was still not optimal, the results of interviews from students for the learning activities were carried out through the provision of material to be studied independently so that it did not bring up the process of students learning to acquire knowledge to transform content into daily life context. It indicated the teacher-centered because students only get intake without being followed by an understanding process. This way, students' critical thinking was less developed. The solution that has been offered was using guided inquiry, emphasizing intellectual development through discovery-based activities [13], using learning tools in the setting of an inquiry model to develop high-order thinking skills, and providing meaning to findings [14].

Building on previously described studies, research that develops critical thinking skills is needed. The STEM approach with problem-based learning with the theme of "innovation to reduce accident rates" produces an unreal product in the form of an innovation development design that includes pretest and posttest questions. This theme was chosen due to its close nature to problems that are often encountered in life like traffic accidents, making it easier for students to construct understanding through direct experience using a PBL model. PBL has the advantage of challenging students' abilities because problem-solving takes place during the learning process, directs the process of transfer of knowledge and transfer of value, and stimulates continuous learning [15]. The STEM approach was suitable for developing critical thinking through the design of intangible products as alternative problems, emphasizing important aspects of designing solutions, building explanations, conducting investigations, interpreting, and analyzing [16].

This particular research has novelties towards a) the development of critical thinking indicators for the adaptation of several figures, b) the development of Watson-Glatser pretest and posttest questions, c) the inclusion of intangible engineering aspects of the STEM approach in the pretest and posttest questions, d) the worksheet compilation process, and e) technological literacy in learning.

METHOD

The research flow can be described in Figure 1.

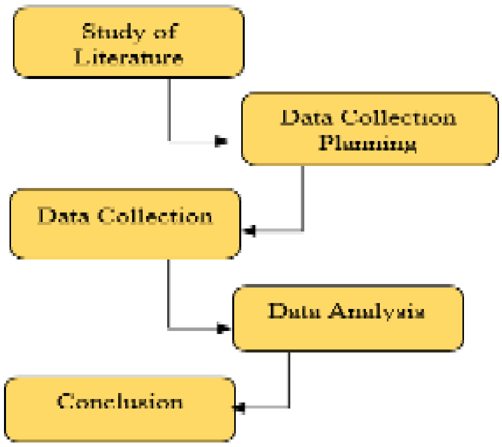

Figure 1. Research Flow

As depicted in Figure 1, the study of literature aims to find relevant information about the research. meanwhile, data collection planning aims to plan data collection, consisting of research location, research design, population, sample, and variables. The research location was at SMAN 1 Purwantoro. The research design was a one-group pretest-posttest design. The method of simple action research was chosen. The population was set to class X MIPA students in the second semester of the 2020/2021 period, with 35 students as the sample. The sampling technique was simple random sampling. As for the variables, the independent variable was set to the problem-based learning model integrated with the STEM approach; meanwhile, the dependent variable was critical thinking skills. Data collection techniques from instruments were in the form of qualitative and quantitative data. The research instrument consisted of cognitive tests of critical thinking and non-tests in the form of questionnaires and observations. Data analysis techniques consisted of instrument validity, prerequisite test, hypothesis testing, pretest-posttest, N-Gain, self-efficacy, response questionnaire, and learning implementation. Instrument validity consists of expert and empirical validity, and expert validation with CVR and CVI. CVR Formula:

$$CVR = \frac{ne - \left(\frac{N}{2}\right)}{\frac{N}{2}} \tag{1}$$

Formula (1) defines CVR (Content Validity Ratio), where *ne* is the number of experts who say appropriate, *N* is the number of experts who validate. *CVI* means CVR [17].

In the empirical validity on 16 students of class X MIPA 1, the decision was determined by the educator. Empirical validity includes the parameters of item validity, reliability, level of difficulty and discriminating power. The validity test is using the product moment formula:

$$r_{xy} = \frac{N\Sigma XY - (\Sigma X)(\Sigma Y)}{\sqrt{(N\Sigma X^2 - (\Sigma X)^2)(N\Sigma Y^2 - (\Sigma Y)^2)}} \tag{2}$$

Source: [18]

Formula (2) defines r_{xy} (correlation coefficient), where ΣX is the number of item scores,

ΣY is the number of scores, and N is the number of samples. The interpretation of the formula is if $r_{xy'} < r_{table}$ then the question is invalid, while if $r_{xy'} > r_{table}$ then the question is valid. Reliability is tested with Spearman Brown's Split-half formula:

$$r_{xy'} = \frac{2r_{xy}}{1+r_{xy}} \tag{3}$$

Source: [19]

Formula (3) defines $r_{xy'}$ (internal reliability of all instruments), where r_{xy} is the product-moment correlation between the first and second halves. Level of Difficulty is tested using the formula:

$$LD = \frac{Mean}{MaximumScore} \tag{4}$$

Source: [20]

Formula (4) defines LD (level of difficulty), where *mean* is the average score of students. Power difference is tested with formula:

$$PD = \frac{\overline{X}_{Upper} - \overline{X}_{Lower}}{MaximumScore} \tag{5}$$

Source: [21]

Formula (5) defines PD (power difference), where $\overline{X}_{Upper}$ is the upper class group average, and $\overline{X}_{Lower}$ (the average of the lower-class group). Analysis of formula test results is counted using:

$$Score = \frac{Score}{MaximumScore} \times 100 \tag{6}$$

The results of the posttest pretest are then analyzed to find N-Gain using the formula:

$$N - Gain = \frac{PosttestScore - \Pr etestScore}{IdealScore - \Pr etestScore} \tag{7}$$

Self-efficacy is tested using the formula:

$$Score = \frac{Score}{MaximumScore} \times 100\% \tag{8}$$

Student learning responses is counted using the formula:

$$Score = \frac{Score}{MaximumScore} \times 100\% \tag{9}$$

Implementation of learning is tested using formula:

$$I = \frac{ManyStepsTaken}{TotalNumberofsteps} \times 100 \tag{10}$$

RESULTS AND DISCUSSION

As stated, data analysis techniques were instrument validity, prerequisite test, hypothesis testing, pretest-posttest, N-Gain, self-efficacy, response questionnaire, and learning implementation. After knowing the results, CVI categorization was done. Expert validation involves 7 validators, consisting of 2 expert lecturers and 5 educators. The results of the syllabus CVI were 0.896, RPP was 0.868, worksheet was 0.959, questionnaire response was 0.959, self-efficacy was 0.959, and test 1 on PBL-STEM implementation was 0.959. The overall mean CVI of the instrument is 0.943, with the validity category being very appropriate. In addition, r_{table} (N 16) is 0.497. The results of the test validity of the 10 description questions contained 7 valid questions and 3 invalid questions. The results of the reliability calculation are 0.809 in the "very high" category, the questions are suitable for research data collection. The results of the calculation of the test difficulty index, 1 question in the easy category and 9 questions in the medium category. Meanwhile, the results of the calculation of the test discriminatory index showed 3 questions in the bad category and 7 questions in the sufficient category. The interpretation of the Kolmogorov-Smirnov normality test is when sig > 0.05, the data is considered normal, while sig < 0.05 is considered not normal.

Table 1. Normality test descriptive

	Kolmogrov-Smirnov			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Pretest	0.176	35	0.008	0.911	35	0.008
Posttest	0.132	35	0.129	0.933	35	0.035

a. Lilliefors Significance Correction

Table 1 shows the results of the normality test on the pretest of 0.008, which is < 0.05. This concluded that the data were not normally distributed. The Sig. posttest showed a value of 0.129, which is > 0.05 so it can be concluded that the data were normally distributed.

Table 2. Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
1.989	1	68	.163

Table 2 displays the results of test of homogeneity of variances. The interpretation of Levene's homogeneity is that when sig > 0.05, it is homogeneous, while sig < 0.05 is not homogeneous. The results of the homogeneity test showed sig. 0.163 > 0.05 so that data is homogeneous.

Table 3. Hypothesis Test Descriptive

	Posttest-Pretest
Z	-4.942[b]
A symp. Sig. (2-tailed)	0.000

a. Wilcoxon Signed Rank Test

b. Based on negative ranks

The interpretation of non-parametric Wilcoxon Signed Rank Test Hypothesis Test sig < 0.05 H_0 was rejected and sig > 0.05 H_0 was accepted. Table 3 shows the results of the hypothesis test descriptive. Results of hypothesis test with Asymp.Sig.(2-tailed) hypothesis test 0.000 <0.05 reject H0, thus there are differences in critical thinking skills before and after learning. It is concluded that the STEM integrated problem-based learning model is effective on improving critical thinking skills of students in class X MIPA.

Table 4. Pretest-Posttest Descriptive Data

Score	*Pretest*	*Posttest*
Highest	75	85.714
Lowest	21.429	42.857
Average	44.286	60
Standard Deviation	10.329	12.426

Table 4 shows the results of pretest-posttest descriptive data. Globally, the average category of students' critical thinking is in the sufficient category.

Table 5. *N-Gain* Descriptive Data

Σ	$\bar{\Sigma}$ *Pretest*	$\bar{\Sigma}$ *Posttest*	*N-Gain*	Category
35	44.286	60	0.282	Low

Table 5 displays the results of the *N-Gain* descriptive data average. From the table, the N-Gain is 0.282 points, showing that it is in a low category.

Table 6. Self-Efficacy Descriptive Data

Score	*Pra*	*Pasca*
Highest	81.667	96.667
Lowest	61.667	53.333
Average	70	70.143
Standard Deviation	5.955	8.521

Table 6 shows the results of self-efficacy descriptive data. Globally, the average category of self-efficacy is in the high category.

Table 7. Learning Responses Descriptive

Total	Average Total Score	Percentage (%)
35	44.514	74.190

Table 7 displays learning responses descriptive. It is reported that the learning responses descriptive is 74.190%, which globally is in the good category.

Table 8. PBL-STEM Implementation Descriptive

Meeting	Total score	Percentage (%)
1	40	93.023
2	43	100

Table 8 presents the implementation of PBL with integrated STEM approach. In general, the PBL-STEM implementation was in the very good category.

The overall process flow of learning activities, including before, during and after learning, is summarized in Figure 2. The research was conducted online. Two online learning meetings were conducted on Wednesday 31 March 2021 and Wednesday 7 April 2021. Pre-learning activities covered information polls, announcements through WhatsApp group, pre self-efficacy questionnaire, zoom link sharing, and pretest. In the pre-learning phase, pretest and pre self-efficacy were given earlier. The distant learning time allocation was 45 minutes to adjust the curriculum implementation in the midst of the Covid-19 pandemic. Learning activities started at 07.30 and ended at 08.15 WIB. The core of learning activities integrated critical thinking indicators, PBL syntax, STEM approach, and worksheet process. The stages of core activities are summarized in Figure 3. Meanwhile, the flow of the core learning activities is described in Table 9.

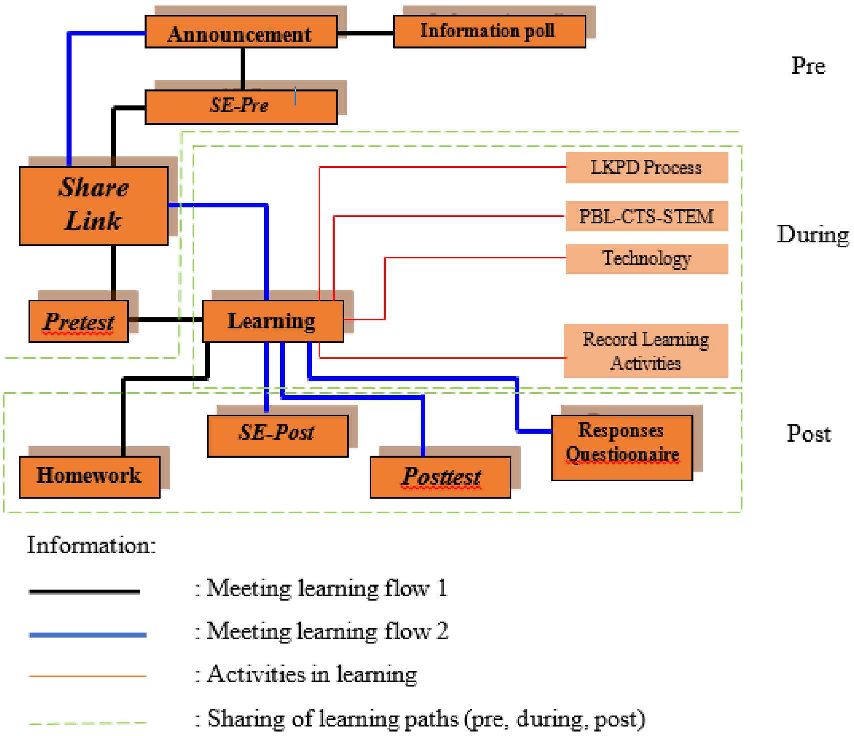

Figure 2. Learning Flow

Table 9. Integration Critical Thinking, PBL, STEM, and Worksheet

Information	Step 1	Step 2	Step 3	Step 4	Step 5
Critical thinking indicator (collaboration and development)	Make and support interpretation	Analyze	Evaluate general and self-evaluating	Create and support inference	Providing a simple explanation of strategy and tactics and continue
Syntax *problem-based learning* (collaboration and development)	Formulate and serving problem	Analyze the problem	Design and implementation solution strategy	Solution reporting and reflection	Review, integration, and evaluation
STEM Approach	Science-Mathematic-Technology	Science-Mathematic-Technology	Science-Mathematic	Science-Mathematic	Science-Mathematic
Development of worksheet process (meeting 1)	*Breaking News*		*Mind Mapping*	Conclusion	
Development of worksheet process (meeting 2)	*Breaking News*			Conclusion	

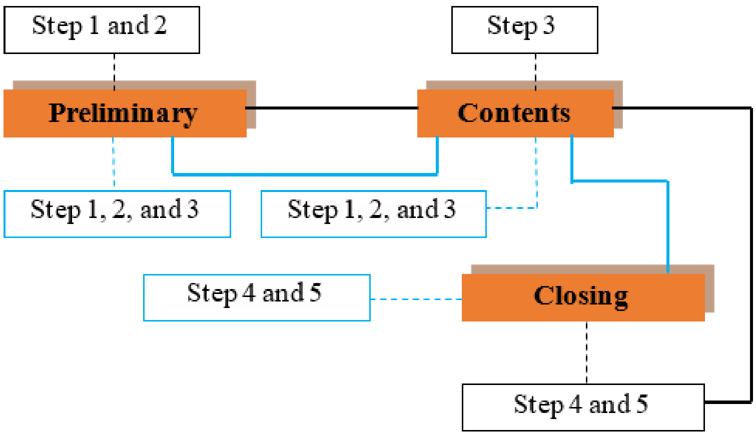

Figure 3. Core learning

Based on Figure 3, the core learning activities begin with an introduction. It is then followed by a worksheet breaking news aimed at directing students to interpret and analyze problems. Worksheet mind mapping aims to direct students to evaluate, infer, reflect, and apply solutions. Next, teachers give momentum and impulse material with PowerPoint supported by simulation. Giving conclusions on worksheets aims to direct students' thinking to draw conclusions. Record learning activities listed in the worksheet process to find out the activities carried out by students during the learning activities. The post-learning activities include twofold: the first meeting and the second meeting. In the first meeting, the post-learning activity is giving homework. Meanwhile, the second meeting's post-learning activities include the distribution of a posttest, post-self-efficacy questionnaire, and response questionnaire. The profile of students' critical thinking skills based on the test results is supported by the results of self-efficacy. The categories of the test results are shown in Figure 4.

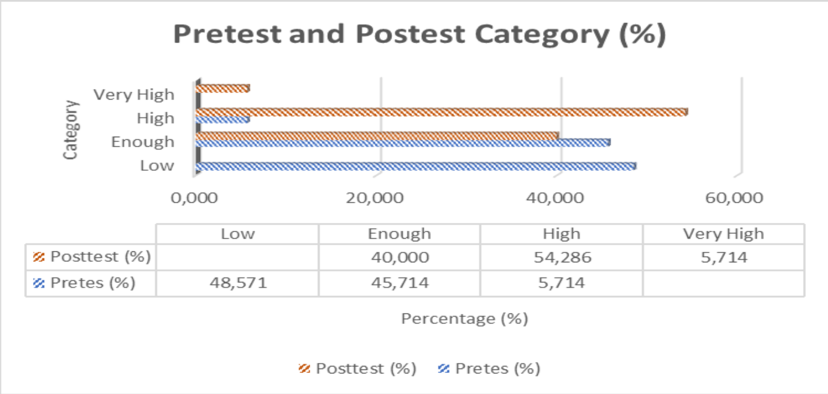

Figure 4. Pretest Posttest Category

Figure 4 shows that the category of students' critical thinking has increased. The highest percentage of the pretest was dominated by low category. Meanwhile, the posttest level increased to the moderate category, showing that the highest percentage was dominated by the high category. The frequency distribution of critical thinking categories is summarized in Table 10.

Table 10. Frequency of Category

Category	Interval Score	Frequency	
		Pretest	*Posttest*
Very low	0-20	-	-
Low	21-40	17	-
Enough	41-60	16	14
High	61-80	2	19
Very High	81-100	-	2

Table 10 shows that the frequency of students' critical thinking categories has increased. The pretest posttest was developed according to critical thinking indicators. The achievements of each indicator are summarized in Table 11.

Table 11. CTS Indicator spread

Number	Indicator	Category		Difference
		Pretest (%)	*Posttest* (%)	
1	A	66.429	77.143	10.714
2	B	41.429	45	3.571
3	C	45	50.714	5.714
4	A	38.571	60.714	22.143
5	D	44.286	60	15.714
6	E	30.714	68.571	37.857
7	D	43.571	57.857	14.286

Information:

Indicator A: Making supports interpretation
Indicator B : Making supports inference
Indicator C: Analyzing
Indicator D: Evaluating general and self

Indicator E : Provide simple and advanced strategies and tactics providing
: Lowest
: Highest

Based on Table 11, the overall increase was due to the problem-based learning treatment that was integrated with STEM. The PBL model improves critical thinking, as the students are accustomed to identifying and finding solutions to problems [22]. In the pretest, the highest indicator was making and supporting interpretation, while the lowest indicator was providing simple and advanced strategies and tactics. In the posttest, the highest indicator was making and supporting interpretation, the lowest one was making and supporting inference. The highest indicators in the pretest and posttest are the students' understanding of linked concepts, describing answers, and writing mathematical equations. The lowest indicators on the pretest are the students have not been able to describe simple ideas and are not used to thinking out of the box. The lowest indicators on the posttest are the majority of students have the same answers in the pretest and posttest, students have not been able to understand the concept, and there were indications of transferring numbers to the formula. The increase in each indicator was different. The fastest-growing indicators were providing simple and advanced strategies and tactics, meanwhile, the lowest-growing indicators were making and supporting inferences. The fastest growth is closely related to learning. This is because the learning carried out by integrating PBL, STEM, critical thinking, and worksheet processes directs students' thinking on achieving the learning goals. Worksheet with STEM approach is able to improve critical thinking skills because there is a process of observing to concluding throughout [23]. During the lesson, the researcher presented the repetition of problems that are related to life. Considering that mastery of the material does not last a short time, periodic repetition is needed. Repetition can overcome forgetfulness, train power, and form the right [24]. Problem-based learning that is presented in relation to life phenomena, namely traffic accidents, bullets, golf games, and pick-up vehicles, where the students have observed directly or experienced it, makes it easier for students to construct understanding from content to context. This is indirectly stored in long-term memory. Problem-based learning provides some benefits: a) fostering critical thinking collaboration and mutual help, b) eliminating the fear of expressing opinions, and c) motivating students to be enthusiastic about learning due to peer pressure [25].

The fastest-growing indicator of providing simple strategies and tactics in learning needs to be maintained in order to further develop students' critical thinking skills. The solution that the researcher offers is to provide a stimulus to students in directing critical thinking based on real problems because it is easier to capture and increases the emphasis on gaining knowledge, not only material intake. On the other hand, the lowest-growing indicator was making and supporting inferences. Judging from the learning activities seen from the results of the students' work on the pretest and posttest, it was known that the students' answers were almost and even the same. It is important to instill concepts. Planting concepts requires a continuous process and time because each student has a different capacity for acceptance and understanding process so it becomes a consideration for researchers and educators in providing feedback .

Referring to the background of the research related to the efforts to reduce the number of traffic accidents through intangible design innovations included in cognitive problems, in this discussion the researchers present samples of each category of critical thinking. The intangible product design sample is summarized in Figure 5.

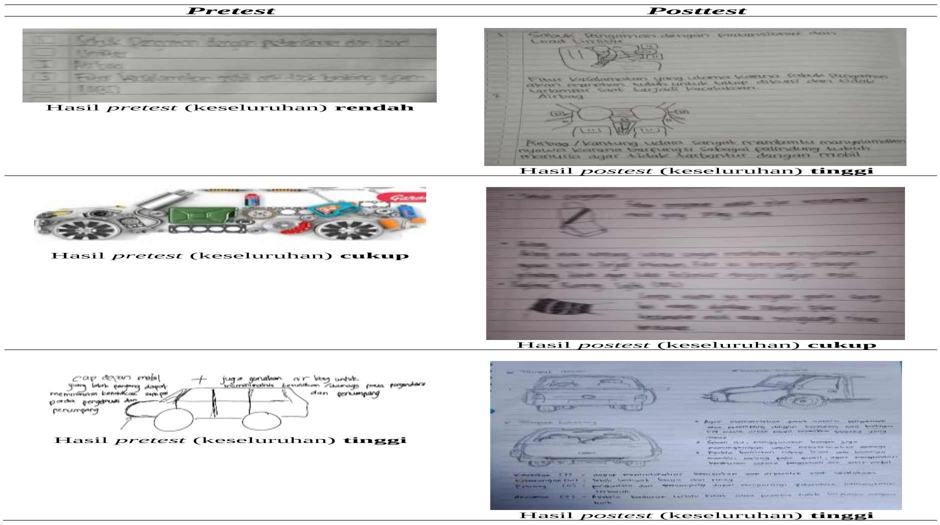

Figure 5. Sample of Design

As shown in Figure 5, the pretest and posttest designs help develop and increase students' critical thinking, especially those related to the design of intangible products. Each student has the basic ability to solve problems and provide alternative solutions or ideas, accordingly to the student's level of understanding. In addition, students' critical thinking can also be seen from the arguments in the SWOT analysis. Providing simple and advanced strategies and tactics at the high school students level seems to have enabled students to develop critical thinking in providing solutions. This is in line with the theory of student development proposed by Jean Piaget, stating that children aged 11 years and over enter the developmental stage of formal operations, where at this stage the child's thinking ability is perfect, they can think deductively, inductively, abstractly, analytically and synthetically [26]. Seeing this indicator experiencing a rapid increase, it becomes a note for researchers and educators in developing test questions that are not only in the form of content but emphasize context and answers that involve direct thinking with broad answers, thus can train students' exploration.

The critical thinking cognitive test that has been carried out is supported by the results of the self-efficacy test. The frequency distribution of the self-efficacy category is summarized in Table 12.

Table 12. SE Frequency spread

Category	Interval Score	Frequency SE	
		Pra	*Pasca*
Low	21-40	-	-
Enough	41-60	-	3
High	61-80	33	29
Very High	81-100	2	3

From Table 12, the frequency of students' self-efficacy categories have fluctuated. As an effort to follow up on the decreasing trends of students' self-efficacy, the researchers conducted open-ended interviews with related students. Based on the interviews, it can be concluded that the underlying reason for their decreased self-efficacy is due to limited time and an unstable network that affects understanding, analyzing, and actively participating, so they tend not to do what is asked in the self-efficacy questionnaire.

Looking at the profiles of the students' pretest and posttest, two students did not experience an increase and one student experienced a decrease. After conducting an in-depth study, the students who did not experience an increase were actually categorized as sufficient, with the self-efficacy increasing and remaining constant, but both did not fill out the worksheet process in learning activities. Meanwhile, one student who experienced a decrease on the pretest in the sufficient category did not fill out the worksheet process in learning activities. Students' critical thinking skills are related to self-efficacy. There is an influence of self-efficacy on critical thinking skills, in which it enables students to analyze and reach understanding [27]. Each individual's self-efficacy is different in different situations. The learning environment influences self-efficacy. The environment in question is a responsive and unresponsive environment. A responsive environment certainly supports the learning process in order to develop critical thinking skills and make learning successful. Low and high self-efficacy is combined with a responsive and unresponsive environment resulting in the possibility of behavior carrying out tasks, depression, effort, and resignation, thus self-efficacy is a predictor of behavior [28].

The measurement of effectiveness in learning refers to indicators of learning effectiveness including student responses, ability to manage learning, and learning outcomes [29]. The effectiveness model is seen from the results of cognitive tests, self-efficacy, responses, and observations of PBL-STEM implementation. Based on the data analysis, the results of the average of the cognitive critical thinking pretest was 44.286 labeled as sufficient category, the average of the cognitive critical thinking posttest was 60 labeled as sufficient category, N-Gain was 0.282 labeled as low category, student response questionnaire was 74.190% labeled as good category, observations on the implementation of PBL-STEM on the first meeting was 93.023% and the second meeting was 100% in the very good category, the average pre self-efficacy of 70 and the average post-meeting self-efficacy of 70.143, in which both are labeled as high category. In general, the problem-based learning model integrated with the STEM approach is effective in improving the critical thinking skills of class X MIPA students with low effectiveness categories. This is because in general there has been an increase, but the increase has not been so significant, one of which is seen in the N-Gain. Basically, the results of the pretest and posttest have increased but not too high, because low N-Gain affects the effectiveness of learning.

The cause of low N-Gain is due to the results of critical thinking cognitive tests, which have not experienced a high increase. As for the no improvement on pretest and posttest, a comparative analysis study of face-to-face and online normal learning was carried out to find out the aspects of demands and analyze future learning needs. In addition, the difference in lesson hours between face-to-face and online learning is reported to be 3 lesson hours in a week, with 45 minutes in each lesson hour in face-to-face learning [30], meanwhile, in distance learning, the education units can choose from 3 curriculum implementation options, namely continuing to use the 2012 national curriculum, using the emergency curriculum (under special conditions), and simplifying the curriculum independently [31]. The implementation of learning activities carried out online as evidenced during the research faced various obstacles including a less stable network, time compression causes some students unable to complete the worksheet process completely, unmonitored student activities, and the majority of students were turning off their camera during the zoom meeting, thus it was not known whether or not they take part in the lesson. In addition, the test work for the level of honesty has not been monitored optimally. Also, the online learning activities were lack of providing fast feedback from the learning activities [32].

The limited time affects especially the intellectual development, because in learning activities it is not only the transfer of knowledge process but there is a process that must be passed so that the transfer of value in learning is realized. Critical thinking skills are high-level thinking processes that require continuous assistance in a long period of time because there are a series of thinking stages that must be developed. In addition to the interaction factor, the interaction in learning activities is important because it trains the social spirit, argue, and equate students' perceptions. In addition, the online learning causes students to minimally interact directly with the their peers. The face-to-face learning emphasizes interactive, while online emphasizes being active. Interactive needs are important because they are able to foster a social spirit. The social spirit of the students can be developed through various activities such as discussions and project collaborations, whereas if one only emphasizes on being active, one tends to emphasize individual abilities or activities which will be dominated by a few students. Activity is important in learning activities, but there are many factors that need to be studied. At some cases, student activity is not evenly distributed, leaving students who want to be active, but they are afraid to ask questions. Furthermore, with a poor internet connection, online learning becomes an obstacle when implementing live activities. This is something that researchers and educators need to consider when carrying out online learning.

Seeing the causes of the N-Gain of students' critical thinking, which is still low, some suggestions given are conducting breakout room through Zoom, optimizing LMS, using video, providing simulation, conducting oral test, implementing PBL-PjBL, and Link-up to improve it. This research has provided a scenario to give opportunities for the students to improve their critical thinking skills in physics. It also gives the teacher the opportunity to apply the learning process that trains critical thinking skills. The problem-based and STEM-integrated learning give impact to the growth of the problem-solver characters.

CONCLUSION

As seen from the average cognitive test score, the critical thinking abilities of students in class X MIPA after experiencing learning with the proposed method increase in the moderate category, and self-efficacy is in the high category. The problem-based learning model integrated with the STEM approach was effective in improving the critical thinking skills of students with low effectiveness categories. However, the research activities carried out were still in the low effectiveness category, it is hoped that further researchers could pay attention to various aspects so that the results are more leveraged in improving critical thinking skills, especially in an online setting. It is recommended for educators to apply STEM-integrated problem-based learning because it affects critical thinking skills and self-efficacy, and is able to bring up the problem-solver spirit of the students.

AUTHOR CONTRIBUTIONS

Zulfawati: article writer ; Tantri Mayasari: article writing advisor; and Jeffry Handhika: article writing advisor.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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