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Enhancing High School Students' Critical Thinking Skills through STEM-PjBL in Optics Topic

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Abstract

Critical Thinking is one of the most crucial skills that must be trained and improved in learning. This study aims to improve students' critical thinking skills using Project-Based Learning (PjBL) model with a STEM approach (STEM-PjBL) on optics topics. This study used a quantitative approach and one group pretest-posttest design. The sampling technique used cluster random sampling and the sample used consisted of 35 students of a class in a public high school at Samarinda. Data collection uses test techniques with 6 questions in the form of essays. The results of this study showed that using STEM-PjBL on optics topics can significantly improve students' critical thinking skills with sig values. (2-tailed) in paired T-test 0.000 and N-Gain 0.74, which is included in the high criteria. After learning, 34% of students are in the highly critical category and 66% in the critical category. The PjBL model with the STEM approach can be used to train the critical thinking skills of high school students.

Keywords: Critical-Thinking; Optics; STEM-PjBL

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INTRODUCTION

Due to rapid changes in science and technology, we must be ready to face various changes. One of the changes we have to face is Society 5.0 (Sakti, 2020). In this era, humans must be able to solve various challenges and social problems with technology and take advantage of innovations during the industrial revolution 4.0. This era is the era of the 21st century, where humans are required to have 21st-century abilities, including the ability to think critically and solve problems, creativity, the ability to collaborate, information technology capabilities, and new forms of literacy as well as social, cultural and metacognitive awareness (Griffin & Care, 2015).

One of the skills needed in the 21st century is critical thinking. In this era, the ability to think critically is one of the crucial skills that every individual must have to work and live effectively in a global society (Linh et al., 2019; Nuraida, 2019). Critical thinking itself is the skill to review and analyze certain information, identify supporting evidence, identify and evaluate assumptions, and apply various strategies to conclude based on assessment standards (Seventika et al., 2018). Education through learning must be able to play an active role in shaping culture, which then develops students' critical thinking skills (Nuraida, 2019).

According to Jan Sermeus et al. (2021), one of the desired educational outcomes is critical thinking, but it is often not well defined in the curriculum. The poor situation causes the learning applied in schools to be dominated by teachers so that they do not train critical thinking skills in students, which is one of the causes of students' low critical thinking skills (Nuryanti et al., 2018).

Nowadays, the rapid advancement of technology has caused terms such as STEM to enter the educational arena, marking a new era in the application of innovative and motivating teaching and learning processes (Hinojo-Lucena et al., 2020). The application of learning that integrates STEM with a focus on the learning process of solving problems in real life has proven to be able to improve students' critical thinking skills. This is due to the STEM approach that could encourage students to learn actively and responsively in various experiments and observations (Davidi et al., 2021).

Many studies have been conducted to improve the critical thinking skills of students. Mutakinati et al. (2018) analyzed students' critical thinking skills using STEM-PjBL. Another study by Yasemin Hacioğlu and Filiz Gülhan used STEM approach learning with *an Engineering Design-Process* (EDP) learning model to improve the critical thinking skills of students in the province of Istanbul, Turkey (Hacioğlu & Gülhan, 2021). Not only that, Putra et al. (2021) state that the EDP learning model can be an alternative method to improve students' critical thinking skills, especially in physics learning.

In 2022, integrating STEM into education to improve 4C skills, especially critical thinking skills, is a new trend among researchers, as conducted by (Khaeruddin & Bancong, 2022), which integrates STEM to improve critical thinking skills through a PhET simulator with results that show significant improvement. In the same year Rizkika et al. (2022) developed STEM-based E-LKPD to improve learners' critical thinking skills. By the end of the year, Oyewo et al. (2022) harnessed PjBL to improve the critical thinking skills of STEM learners using water treatment activity, this activity involved the development of a novel product using agricultural wastes for efficient water treatment and enhanced STEM students' critical thinking skills.

According to Laboy-Rush (2010), STEM-PjBL learning has five steps, each aiming to achieve a specific process. The five stages consist of 1) Reflection; 2) Research; 3) Discovery; 4) Application; and 5) Communication.

There has been a lot of research in various regions regarding the influence of STEM-based learning. However, there is still very little research related to the application of STEM learning to improve students' critical thinking skills, especially in physics learning. It is interested in exploring how STEM-PjBL can enhance students' critical thinking skills. The PjBL learning model is understood as a learning model that promises to improve learner learning (Guo et al., 2020). As for the implementation of learning in this study, students will become the center of learning activities. With the student-centered and using STEM-PjBL learning model, students' critical thinking skills will improve as long as they acquire knowledge and skills by working long enough to investigate and respond to exciting and complex questions, problems, or challenges.

In optics topic, there are many tools used in everyday life, but to learn the working principle of optical tools, many schools do not have these facilities, so by applying the STEM-PjBL learning model, it is hoped that students can learn the working principles of optical tools and enhance students critical thinking skills.

METHOD

This study aims to improve the critical thinking skills of class XI SMA N 5 Samarinda consisting of 35 students. This research uses a quantitative approach with the type of quasi-experimental research and the design of one group pretest-posttest study.

The data collection technique used is a test to determine students' critical thinking skills before and after receiving treatment. The treatment given is in the form of the application of STEM-PjBL learning. The pretest and posttest questions are the same; as many as six essay-shaped questions are given before and after all learning activities are completed. The description of the critical thinking skills is shown in Table 1.

Table 1 Description of the critical thinking skills test

No	Critical Thinking Sub-Skills	Indicators	Number of Question Items
1	Interpretation	Students can express the meaning of a given physics statement	1
2	Analysis	Students can analyze the arguments given	1
3	Inference	Students can conclude on logical grounds	1
4	Evaluation	Students can assess the statements given	1
5	Explanation	Students can explain the answer.	1
6	Self-Regulation	Students can find errors in problem-solving	1
Number of Question Items			6

The data analysis technique used is an inferential technique. Inferential analysis, as a prerequisite test is carried out normality test. A paired T-test was previously carried out to determine whether there was an increase, which was then continued with the N-Gain test. All data analysis was carried out assisted by IBM SPSS v.25.0 for windows software.

RESULT AND DISCUSSION

From the study results, data on the pretest and posttest results of class XI MIPA 5 students were obtained on the material of optical tools. The data represents students' critical thinking skills before and after being given treatment. Before processing the data, a prerequisite test is first carried out, namely a normality test, with results shown in Table 2.

Table 2 Test of normality results

Tests of Normality						
	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistics	Df	Sig.	Statistics	Df	Sig.
Pretest	.087	35	.200	.946	35	.086
Posttest	.160	35	.023	.950	35	.116

Based on the output of the normality test in Table 2, using the Shapiro-Wilk technique, it is known that the pretest significance value is 0.086 and the posttest significance value is 0.116, so it can be said that the data is distributed normally.

Furthermore, a paired T-test was carried out, with results shown in Table 3.

Table 3 Paired t-test results

Paired Samples Test								
	Paired Differences					t	Df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pretest - Posttest	-59.80	9.32	1.57	-63.00	-56.60	-37.94	34	.000

Based on the paired T-test output, as shown in Table 3 the Sig value is known. (2-tailed) of 0.000 i.e. smaller than 0.05. So it can be said that there is an average difference from the data on the value of the pretest and posttest results of students in learning optical tools with a STEM-PjBL model.

Improving students' critical thinking skills can be seen by conducting an N-Gain analysis. The results of the N-Gain analysis on the average pretest and posttest values are shown in Table 4.

Table 4 N-Gain analysis results

Average Pretest	Posttest average	N-Gain	Criterion
19.68	79.48	0.74	High

Based on the analysis of the N-Gain value, it is known that the N-Gain value of students is 0.74 and is included in the high criteria. The criteria of each learner are shown in Table 5.

Table 5 Criteria of N-Gain value

N-Gain Value	Criterion	*f*	Percentage
N-Gain ≥ 0.7	High	26	74,29 %
0.3 <N-Gain < 0.7	Average	9	25,71 %
N-Gain ≤ 0.3	Low	0	0 %

Data on the results of students' pretest and posttest scores are categorized based on students' critical thinking abilities, as shown in Table 6.

Table 6 Categories of students' critical thinking skills

No	Value Conversion (Scale 0-100)	Pretest	Posttest	Category
1	100-86	0	4	Highly Critical
2	85-81	0	8	
3	80-76	0	15	Critical
4	75-71	0	7	
5	70-66	0	1	
6	65-61	0	0	Quite Critical
7	60-56	0	0	
8	55-51	0	0	
9	50-46	0	0	Less Critical
10	45-0	35	0	

The average results of pretest and posttest scores on each sub-skills of critical thinking students of class XI MIPA 5 Samarinda can be seen in Figure 1.

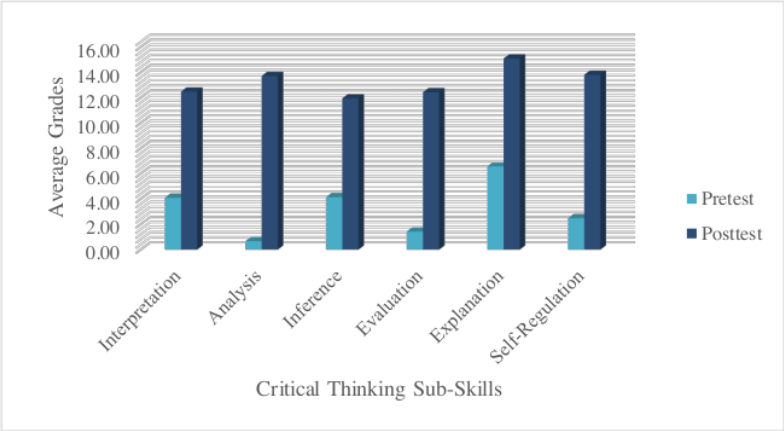

Figure 1 Diagram of the average grades on each sub-skill

Figure 1 shows that the average results of obtaining pretest and posttest scores show the highest average difference from the critical thinking sub-skills that occur in the analysis sub-skill of analysis because students are still unable at the pretest to analyze the statements and questions given. Students can quickly analyze the statements and questions given at the posttest because they have previously conducted learning activities and project creation. In general, the results of this study show that STEM-PjBL learning can improve students' critical thinking skills in every aspect.

In 2022, research conducted by Roslina et al. (2022) showed that the use of STEM-PjBL can be integrated with media or material teaching and positively affects learning physics. This research, carried out in the even semester of the 2021/2022 academic year in March-April, aims to find out how to apply the STEM-PjBL learning model to improve students' critical thinking skills.

The success rate of improving students' critical thinking skills through pretest and posttest can be known by looking for N-Gain values. Based on the data obtained from processing pretest and posttest data using IBM SPSS v.25.0 for windows, the N-Gain value obtained is 0.74, which is included in the high category.

Criteria N-Gain value based on data analysis that has been carried out showed that 26 students belong to high criteria and nine others include medium criteria. According to the category of critical thinking skills of students Priantari et al. (2020)), on the pretest score, all students are included in the less critical category. In the posttest score, 12 out of 35 students are included in the highly critical category, and 23 out of 35 students are included in the critical category.

Isnaini and Djamilah (Azizah & Widjajanti, 2019) said that PjBL with learning steps that can train students' critical thinking skills is effective in improving critical thinking skills. In the project design step, students strive to design a project creation process that will be taken in solving problems that will lead students to make their own decisions, and this is supported by Hosnan and Sikumbang (2014), at PjBL could encourage students to think critically, solve problems, collaborate, and try various forms of communication. In addition, students also make their own decisions within a predetermined framework. Another study conducted by Jamaludin concluded that PjBL could significantly improve students' critical

thinking skills compared to conventional learning (Jamaludin, 2017) and other research conducted by Setia Permana et al. showed that STEM approaches could significantly improve learners' critical thinking skills (Permana et al., 2021).

Improving the critical thinking skills of students in this study can be achieved by applying STEM-PjBL learning. Students had learning by using real-life subjects such as optics and they use appropriate media by real learning media such as the prototype of projectors (Hikmah & Jauhariyah, 2021). Based on the average results of the pretest and posttest scores shown in figure 4.2, the highest increase in critical thinking sub-skills occurred in the analysis sub-skills. In general, the study's results showed that STEM-PjBL learning could improve students' critical thinking skills in every sub-skill.

The increase in critical thinking skills experienced by students is due to the early stages of PjBL, which gives students directing questions that have a substantial effect on achieving the goals of critical thinking skills (Jamaludin, 2017). This is also supported by Azizah & Widjajanti (2019), who stated that effective PjBL is in terms of students' learning achievement, critical thinking skills, and self-confidence. The PjBL learning model has its value where learning activities contain real problems, give appreciation to the results of student projects, the autonomy of students in the learning process, and support the learning process based on learning by doing so that the PjBL model can better improve students' critical thinking skills (Priantari et al., 2020).

CONCLUSION

Based on the results of research and data analysis carried out, after being given treatment in the form of a learning optics topic with a STEM-PjBL learning model, it can be concluded that there is a significant increase. After learning, 12 out of 35 students were in the highly critical category, and 23 out of 35 students were in the critical category. For further research advice, it would be better to integrate STEM-PjBL into learning, especially physics learning on other materials to improve 4C skills.

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