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Enhancing Critical Thinking Skills and Learning Outcomes through STEM Project-Based Learning in Energy Transformation Topic

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ABSTRACT

This study aims to improve students' learning outcomes and critical thinking skills using the STEM-based Project-Based Learning (PjBL) model. The research was conducted on fourth-grade students at SD Negeri Bulakan 01, Sukoharjo, in the 2023/2024 academic year. This study is a Classroom Action Research (CAR), in which the teacher acts as the learning implementer, while the researcher serves as an observer. The research design follows the model developed by Kemmis and McTaggart. The study was conducted during the even semester of the 2023/2024 academic year, specifically in February. The subjects of this study were fourth-grade students at SD Negeri Bulakan 01, consisting of 16 students, while the object of the study was students' critical thinking skills. Data were collected through observation and interviews, then analyzed descriptively and presented in tables and graphs. The results of the study showed an improvement in students' critical thinking skills and learning outcomes. In Cycle I, students' critical thinking skills reached 63.3%, categorized as moderate. In Cycle II, these skills increased to 76.7%, categorized as good, indicating a 13.4% improvement. The average student score increased from 72 in Cycle I to 82 in Cycle II. Based on the data, it was found that in Cycle I, 8 students (50%) met the Minimum Mastery Criteria (KKM). In Cycle II, the number of students who met the KKM increased to 12, raising the mastery percentage to 75%. The achievement of classical learning outcomes in Cycle II met the success indicators, as students achieved individual mastery of ≥ 75%. Thus, the use of the STEM-based Project-Based Learning (PjBL) model in the Integrated Science subject has been proven to enhance learning outcomes and critical thinking skills among fourth-grade students at SD Negeri Bulakan 01.

Keywords: *Critical thinking skills, Learning Outcomes, Project-Based Learning, STEM*

INTRODUCTION

Learning with a new paradigm, currently known as the *Merdeka Belajar* curriculum, emphasizes the importance of student-centered learning practices. The implementation of the *Merdeka Belajar* curriculum aims to address educational challenges in the era of the Fourth Industrial Revolution. According to Zarkasi (2022), with this new paradigm, teachers or educators are given the freedom to design learning and assessments that align with the characteristics and needs of each student. This new learning paradigm includes six dimensions in the *Profile of Pancasila Students*, which consist of abilities, competencies, or characteristics that every student must develop. These six dimensions serve as guidelines and directives for all educational policies, including the learning and assessment process. The

Ministry of Education, Culture, Research, and Technology (2021) states that these dimensions are designed to ensure that education in Indonesia produces competent and character-driven generations in accordance with the values of Pancasila.

One of the dimensions developed in the *Profile of Pancasila Students* is critical reasoning ability. This ability involves processing information both qualitatively and quantitatively, establishing connections between various pieces of information, as well as analyzing, evaluating, and drawing conclusions from that information. The elements of critical thinking include acquiring and processing information, analyzing and evaluating reasoning, reflecting on thoughts and thinking processes, and decision-making (Ministry of Education, Culture, Research, and Technology, 2021). Overall, critical reasoning or critical thinking is an essential component that must be developed in the *Merdeka Belajar* curriculum. This is crucial to ensure that students are not only able to understand the information they receive but also capable of analyzing, evaluating, and effectively utilizing that information in decision-making and problem-solving.

One of the student-centered learning models in the new paradigm that can enhance critical thinking skills is Project-Based Learning (PjBL). This project-based learning model facilitates material comprehension by involving hands-on practice rather than relying solely on abstract concepts. Through PjBL, students can analyze problems, provide critical responses, and find solutions while also enabling teachers to deliver meaningful learning experiences (Dywan & Airlanda, 2020). The PjBL syntax consists of six stages: 1) Identifying essential questions (*start with essential questions*), 2) Designing the project implementation (*design a plan for the project*), 3) Creating a schedule (*create a schedule*), 4) Monitoring students and project progress (*monitor the students and the progress of the project*), 5) Assessing the outcome (*assess the outcome*), and 6) Evaluating the experience (*evaluate the experience*) (Suryaman, 2020). In the learning process, the first three stages are conducted in the first session, while stages four to six take place in the following session.

STEM (Science, Technology, Engineering, and Mathematics) provides education and training that engage students in various essential skills. These include fostering critical thinking, conducting in-depth investigations, solving complex problems, working collaboratively in teams, and applying engineering principles through a design-based approach. Thus, STEM is not only focused on theoretical knowledge but also on developing practical and collaborative skills necessary in real-world applications. STEM integrates these four disciplines harmoniously within learning processes closely related to real-life problem-solving. It offers a systematic framework for analyzing materials or issues under discussion. PjBL and STEM complement each other with their respective strengths and limitations, enabling students to understand product development concepts supported by the PjBL model and the engineering design process, including planning and redesign. This integration allows for the creation of well-structured and appropriate final products (Lutfi, Ismail, & Andi Asmawati Azis, 2018).

STEM-based PjBL is an integration of Project-Based Learning and the STEM approach, which can enhance students' learning interest, provide meaningful learning experiences, and help them develop problem-solving skills and support their future careers. This learning model also presents challenges and motivation for students, as it trains them to think critically, conduct analyses, and improve higher-order thinking skills (Tseng et al., 2013 & Capraro et al., 2013, in Afriana, 2016). Thus, the combination of Project-Based Learning (PjBL) and STEM can optimize learning activities, support learning success, and strengthen students' mastery of concepts and critical thinking skills.

Based on interviews with fourth-grade teachers, the main issue in learning is the low level of students' critical thinking skills. The researcher's observations indicate that students tend to be passive in asking questions, participating in discussions, and analyzing problems. Students also hesitate to express their opinions, rely only on reading materials from textbooks, and struggle with problem-solving. For example, when the teacher explains energy transformation in a contextual manner, students still find it difficult to identify and classify the concepts. Additionally, students' learning outcomes in the topic of energy transformation and transfer have not yet met the Minimum Competency Criteria (KKM), with an average daily test score of only 72, compared to the required 75. To address this issue, teachers need to implement a learning approach that encourages active participation and enhances students' critical thinking skills while developing well-structured Teaching Modules (MA). One possible solution is the implementation of the STEM-based Project-Based Learning (PjBL) model (Dywan & Airlanda, 2020).

The author firmly believes that this learning method is highly suitable for the IPAS learning process at SD Negeri Bulakan 01 Sukoharjo. A supportive environment and engaging learning activities can foster and increase students' motivation to learn IPAS. As a result, complaints such as boredom, fatigue, and lack of interest—frequently expressed by students during IPAS lessons—can be effectively addressed through the STEM-based PjBL model. This reality has motivated the author to conduct a Classroom Action Research (CAR) study titled "Enhancing Critical Thinking Skills and Learning Outcomes Using the STEM-Based Project-Based Learning (PjBL) Model in the IPAS Subject on Energy Transformation for Fourth-Grade Students at SD Negeri Bulakan 01."

METHOD

This study employs a Classroom Action Research (CAR) method with a qualitative approach. The CAR design was chosen as it provides an in-depth understanding of the implementation of the STEM-based Project-Based Learning (PjBL) model in improving learning outcomes and critical thinking skills in the Social Science and Natural Science (IPAS) subject, specifically on the topic of energy transformation for fourth-grade students at SDN Bulakan 01 Sukoharjo.

The research was conducted at SD Negeri Bulakan 01 Sukoharjo. The subjects of this study, who also received the intervention, were fourth-grade students of SD Negeri Bulakan 01 Sukoharjo for the 2023/2024 academic year, consisting of 16 students. The research objects were learning outcomes and critical thinking skills.

In accordance with the selected research type, which is Classroom Action Research, this study was conducted in two learning cycles. It specifically examined students' learning outcomes in the IPAS subject. The research process consisted of several stages, with each cycle including the phases of planning, action, and reflection. The data collection techniques used in this study were observation and tests.

RESULT AND DISCUSSION

Based on the implementation of actions over two cycles, data indicate that students' critical thinking skills have improved. The improvement in students' critical thinking skills was observed through the application of the Project-Based Learning (PjBL) model.

Table 1
Observation Results of Students' Critical Thinking Skills Using the STEM-Based PjBL Learning Model

Siklus I	Siklus II
60,6%	75,8%
Cukup	Baik

Based on the table above, the percentage of critical thinking skills observed in students using the STEM-based Project Based Learning (PjBL) model in Cycle I was 60.6%, categorized as sufficient, whereas in Cycle II, it increased to 76.7%, categorized as good. The observation results indicate a 15.2% improvement in students' critical thinking skills from Cycle I to Cycle II.

The progress in students' critical thinking skills can be identified through evaluation results conducted in the first and second cycles. These evaluations demonstrate a significant improvement in students' ability to analyze, evaluate, and critically solve problems. The findings from both cycles provide a clear picture of the enhancement of students' critical thinking competencies, reflecting the effectiveness of the implemented teaching strategies and the students' efforts in improving their skills, as outlined below:

Table 2
Evaluation Results of Students in Cycle I and II for IPAS Subject on Energy Transformation Material

Kriteria	Siklus I	Siklus II
Rata-rata	72	82
Nilai tertinggi	85	95
Tuntas KKM	8	12
Belum Tuntas KKM	8	4
Presentase Ketuntasan KKM	50%	75%

Based on the research conducted, it was found that students' learning outcomes in the IPAS subject improved through the implementation of the STEM-based Project Based Learning (PjBL) model. The average student score increased from 72 in Cycle I to 82 in Cycle II. According to the data, the number of students who met the Minimum Competency Criteria (KKM) in Cycle I was 8 students, accounting for 50% of the total participants. In Cycle II, the number of students achieving competency increased by 12, raising the overall KKM completion rate to 75%. The attainment of learning outcomes in Cycle II has met the success indicators, as students achieved individual learning mastery of ≥ 75%. When analyzed in detail based on each element of STEM (Science, Technology, Engineering, Mathematics), the students' achievements are as follows:

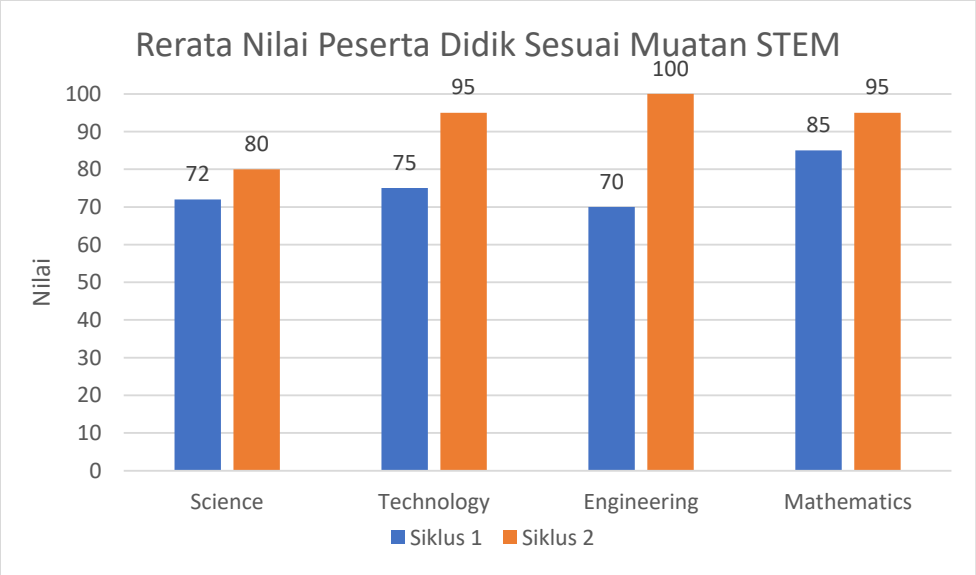

Figure 1
Average Student Scores Based on STEM Components

Based on the diagram above, the average student score in the science component during Cycle I was 72, categorized as good, while in Cycle II, the average score increased to 80, also categorized as good. Meanwhile, in the technology component, the average student score in Cycle I reached 75, classified as good. In Cycle II, the average score increased significantly to 95, which falls under the very good category. This improvement demonstrates remarkable progress in students' understanding and technological skills. This positive change reflects the success of the teaching methods applied and the dedication of educators in guiding students toward better learning outcomes. For the engineering/motor skills component, the average student score in Cycle I was 70, categorized as sufficient, while in Cycle II, the average score increased to 100, classified as very good. In the mathematics component, the average student score in Cycle I was 85, categorized as very good, and in Cycle II, the average score increased to 95, also classified as very good. These findings indicate a significant improvement in students' scores across all STEM components.

Thus, the implementation of the STEM-based Project Based Learning (PjBL) model in IPAS learning has made the learning process more meaningful, engaging, and encouraged student participation. This model promotes active student involvement in solving real-world problems through critical thinking and exploration. In PjBL, students actively seek solutions to given problems. Through demonstration methods, teachers can illustrate step-by-step problem-solving approaches, allowing students to understand concepts more deeply and practically. This approach makes learning more meaningful as it directly relates to real-life situations. Additionally, the PjBL-based STEM method creates an enjoyable learning atmosphere, where students experience satisfaction upon successfully solving problems and demonstrating their understanding to their peers. Consequently, STEM-based PjBL enhances students' critical thinking skills and learning outcomes, making the learning process meaningful, enjoyable, and fostering a sense of enthusiasm in the classroom.

CONCLUSION

Based on the results of the conducted research, the following conclusions can be drawn: a) The implementation of the STEM-based Project Based Learning (PjBL) model in IPAS learning for fourth-grade students at SD Negeri Bulakan 01 successfully enhanced students' critical thinking skills and learning outcomes significantly. The application of this learning model demonstrated a substantial improvement. b) The average percentage of critical thinking skills in Cycle I was 60.6% (categorized as sufficient), which increased to 75.8% (categorized as good) in Cycle II. This improvement indicates the effectiveness of the STEM-based PjBL approach in developing students' critical thinking abilities. c) The average student score increased from 72 in Cycle I to 82 in Cycle II. Based on this data, it was found that in Cycle I, 8 students (50% of the total students) met the Minimum Competency Criteria (KKM). In Cycle II, the number of students meeting the KKM increased by 12, bringing the KKM completion rate to 75%. The overall learning achievement in Cycle II met the success indicators, as individual student learning mastery reached ≥ 75%.

Although the implementation of the STEM-based Project Based Learning (PjBL) model in Cycle I had some shortcomings, the improvements made in Cycle II successfully addressed these issues. These improvements included providing reinforcement to encourage students to express their opinions and answer questions, motivating students to pay close attention to whoever was speaking, fostering active participation through praise or rewards, and giving students the freedom to voice their thoughts. Teachers also provided more intensive guidance to students, while researchers and teachers engaged in discussions regarding unimplemented learning steps. After these refinements, a significant improvement was observed in Cycle II, with the average percentage of critical thinking skills reaching 75.8% (categorized as very good) and the KKM learning mastery rate achieving 75% (categorized as good).

The researcher offers the following recommendations: For Schools: It is recommended that schools provide training for teachers to implement various teaching models, including the STEM-based Project Based Learning (PjBL) model. This is essential to create an engaging and active learning environment that allows students to achieve optimal learning outcomes. For Teachers: Teachers are encouraged to incorporate the STEM-based Project Based Learning (PjBL) model as a teaching variation. Additionally, they should consistently provide motivation and encouragement to students, fostering active participation in learning activities, which in turn will enhance their critical thinking skills. For Future Researchers: Further studies on the implementation of the STEM-based Project Based Learning (PjBL) model are recommended. Researchers are also encouraged to further develop this model to maximize its effectiveness in improving students' critical thinking skills.

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